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REPORT OF THE COMMITTEE ON A TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY

1946 - 1947

HARRY S. LADD, CHAIRMAN

KENNETH E. LOHMAN, VICE-CHAIRMAN

Division of Geology and Geography
National Research Council
Washington, D. C.

NATIONAL RESEARCH COUNCIL
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NATIONAL RESEARCH COUNCIL

DIVISION OF GEOLOGY AND GEOGRAPHY

WASHINGTON, D. C.

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1946 - 1947

Presented in preliminary form as Appendix H
at the Annual Meeting of the Division
May 2, 1947

* (No. 7 in this Series. See page 93
for list of previous reports)

COMMITTEE MEMBERS (1947)

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Kenneth E. Lohman, Vice Chairman for Geology
Roger Revelle, Vice Chairman for Oceanography

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(First edition, March 1948)
(Reissued without change, February 1951)

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REPORT OF THE COMMITTEE ON

TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY[1]

INTRODUCTION

During the year the Chairman and Vice-Chairman corresponded with other Committee members and several were visited in the field. On January 15 most of the members resident in Washington attended a meeting of the Paleontological Society of Washington which was devoted to ecology and paleoecology. Dr. Vaughan and Mr. Ladd spoke briefly about the Committee and its work.

A two-day meeting of the Committee was held March 10-11 in Washington with six members and five invited guests present. The sessions were devoted almost entirely to the formulation of concrete plans for the preparation of the Treatise on Marine Ecology and Paleocology.

A symposium on marine ecology was held May 21 with the Paleontological Society of Washington. Gordon Gunter, a biologist member of the Committee, came to Washington to conduct the meeting. The meeting was held at the National Museum, about 35 members and guests of the Society attending. Mr. Gunter opened the meeting with a talk on marine ecology and Mr. Ladd spoke briefly of the work of the Committee. A general discussion followed, those present giving general approval to the Committee's program and offering a number of valuable suggestions.

Following recommendations made in a Preliminary Report submitted in April 1947, four new members were appointed to the Committee:

Dr. Richard Fleming, U. S. Hydrographic Office
Dr. Julia Gardner, U. S. Geological Survey
Dr. John B. Reeside, Jr., U. S. Geological Survey
Dr. Waldo L. Schmitt, U. S. National Museum

As now constituted the Committee membership totals 16, of which 7 are geologists, 6 are biologists, and 3 are oceanographers. K. E. Lohman has been designated Vice-Chairman for Geology, Gordon Gunter, Vice-Chairman for Biology, and Roger Revelle, Vice-Chairman for Oceanography. No further additions to the membership are contemplated in the near future but each Vice-Chairman may organize a sub-committee of which he would be chairman and as such permitted to appoint a panel to assist in the work.

TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY

GENERAL

During the meetings held in March 1947 it was agreed that although the Treatise would deal with both ecology and paleoecology and therefore be of interest to both biologists and geologists the emphasis should remain geological.

1/ Following a suggestion made by the Division of Geology and Geography, the new title given above has been substituted for the earlier name "Committee on Marine Ecology as Related to Paleontology."

The Treatise will be written with the needs of the paleontologists specifically in mind. It is recognized that many organic groups that are of importance to biologists have left little or no fossil record. Such groups will be treated lightly in the Treatise, thus somewhat simplifying the task of treating the ecology of living marine organisms.

As now planned the Treatise will be published in two volumes, one containing the text much as outlined in last year's report, the other containing the annotated bibliographies. Volume one will be fully illustrated, particular attention being given to "ecological and paleoecological pairs"; i.e., photographs of the sea bottom or sections of Recent sediment cores to be placed alongside photographs of similar environments preserved as ancient sediments. K. O. Emery and K. E. Lohman will be largely responsible for the selection and arrangement of the illustrations. Suggestions or information about suitable illustrations--either published or unpublished--will be welcomed.

A number of changes have been made in the outline as published in last year's report. To the biological feature there is to be added a discussion of the morphological features of the organisms themselves. Likewise to be added is a general preamble on the effects of latitude. It will also probably prove desirable to add an introductory chapter dealing with the methods of ecological investigation.

STATUS OF ASSIGNMENTS

Selected Analyses from Geologic Record

During the meetings held in March 1947, the tentative list of analyses given in last year's annual report was slightly altered and expanded. All assignments in this section of the Treatise have now been made and it is expected that several of the units will be completed at an early date so as to be included in forthcoming annual reports. The complete list of assignments is given below.

RECENT	Gulf Coast	Gordon Gunter, Joel Hedgpeth, W. Armstrong Price, and H. S. Ladd
RECENT	California	G. E. MacGinitie and K. O. Emery
PLEISTOCENE	Gulf Coast	H. S. Ladd
PLEISTOCENE	California	W. P. Woodring
TERTIARY	Gulf Coast	Julia Gardner
TERTIARY	California	Ralph Stewart
CRETACEOUS	Rocky Mountains	J. B. Reeside, Jr.
JURASSIC	Rocky Mountains	Ralph Imlay
TRIASSIC	Western Great Basin	S. W. Muller
PERMIAN	Trans-Pecos Region, Texas	Norman Newell and G. A. Cooper

PENNSYLVANIAN	Eastern Interior of U. S.	J. Marvin Weller
MISSISSIPPIAN	Upper Mississippi Valley	James Steele Williams
DEVONIAN	Eastern U. S.	G. A. Cooper
SILURIAN	Appalachian Region	Frank M. Swartz
ORDOVICIAN	Llano Uplift	Preston Cloud and Virgil Barnes
CAMBRIAN	Rocky Mountains	Christina Lochman Balk
PRE-CAMBRIAN	Northwestern U. S.	Carroll Lane and Mildred Adams Fenton

The Committee has long felt that the publication of the Treatise would stimulate much-needed research in the field of Paleoecology. Several of the replies recently received by the Committee in response to letters asking the cooperation of prominent paleontologists in preparing the "Selected analyses from the geologic record," have indicated that these requests have in themselves acted as spurs to fundamental research. This has been very gratifying.

Annotated Bibliography of Marine Ecology

Three additional assignments were made during the year, as follows:

Marine algae - Dr. R. H. Williams, University of Miami

Brachiopods - Dr. G. A. Cooper, U. S. National Museum

Crustacea - Dr. Waldo L. Schmitt and Dr. C. H. Edmondson, U. S. National Museum and Bernice P. Bishop Museum, Hawaii, respectively

At the meeting held in March 1947 it was agreed that the style of citation of the annotated bibliographies should be that used by the U.S.G.S. Bibliography of North American Geology. As published in the Treatise each bibliography will have a finding index.

Dr. Cooper's review of the literature on Recent brachiopods has been completed and is reproduced on pages 38-44 of this report. Also included is Dr. Earl Myers' review of the literature on living Foraminifera (pp. 28-37). Dr. Myers' contribution contains a list of 9 general and 68 special references. Accompanying these references is an account of the biology and habits of Foraminifera and a discussion of the ecologic factors that influence their distribution. References to many of the articles listed are included parenthetically in the text. This mode of treatment has the advantage of continuity and gives a comprehensive over-all picture. It is not, however, an annotated bibliography and many of the references are not cited in the text. As Dr. Myers points out it is a "Working Bibliography." The Committee reproduces it as submitted, and will

welcome expressions of opinion as to the desirability of the mode of treatment. Corrections or additions to either of the above-mentioned contributions will be welcomed by the Committee.

Annotated Bibliography of Paleoecology

Three assignments were completed during the year and all are reproduced in the present report so that they may serve as guides in the completion of other assignments.

CURRENT ACTIVITIES

EASTERN UNITED STATES

Dr. Rousseau H. Flower, Assistant State Paleontologist of New York, is gathering material for a study of trails and tentacular impressions many of which clearly made by Nautiloids.

Dr. John B. Reeside, Jr. of the U. S. Geological Survey states that detailed paleontologic and ecologic studies have been made of cuttings from three deep wells drilled by oil companies on the eastern shore of Maryland (Ocean City 7,710 feet, Salisbury 5,568 feet, Berlin 7,178 feet). J. L. Anderson of Johns Hopkins described the lithology and had general supervision over the work; diatoms were studied by K. E. Lohman, Foraminifera by Joseph A. Cushman and Ann Dorsey, Mesozoic mollusks by L. W. Stephenson, Tertiary mollusks by Julia Gardner, ostracodes by Fred M. Swain. All three wells reached the crystalline basement rocks. The completed report will be published by the Maryland Department of Geology, Mines and Water Resources. Dr. Swain is also studying samples from two deep wells drilled by the Standard of New Jersey in the Cape Hatteras area. Foraminifera from these wells will be studied by Dr. W. Storrs Cole of Cornell University. The first of these wells (N.C. Esso No. 1) was drilled to 10,054 feet, reaching crystalline rock. N.C. Esso No. 2 was stopped at 6,410 in Lower Cretaceous rocks.

Prof. Thos. A. Stephenson of the University of Wales in Aberystwith has been awarded a fellowship from the Penrose Fund of the American Philosophical Society to Study the general biology of animals and seaweeds between tide marks in American environments on both east and west coasts. Prof. Stephenson will be assisted in his studies by Mrs. Stephenson.

Dr. Frank M. Swartz of Pennsylvania State College has completed a comprehensive study of faunal development, conditions of deposition and paleogecgraphy of late Ordovician, Silurian and early Devonian strata in the middle Appalachian region. The results will be published by the Pan-American Institute of Mining Engineering and Geology.

At Woods Hole Oceanographic Institution C. J. Fish is completing the compilation under Navy contract of a bibliographic card index of approximately 8,000 titles pertinent to Pacific Ocean biology. Dr. Gordon Riley is organizing available data for quantitative plankton analyses in the western North Pacific.

MIDDLE UNITED STATES

Prof. Ralph W. Dexter of Kent State University, Ohio, is undertaking an ecological study of the barnacles under the direction of Dr. J. Paul Visscher.

Gordon Gunter of the Institute of Marine Science, University of Texas, reports that the first unit of the new Marine Laboratory has been opened on Mustang Island at Port Aransas, Texas. Dr. Gunter is continuing his studies of catastrophism in the sea and its paleontological significance. Records indicate that mass mortalities of marine animals in shallow water may occur thousands of times in a million years. In the region of the Gulf of Mexico such events are an important factor in the fossilization of the fauna.

Mr. Heinz A. Lowenstam of the Illinois State Geological Survey will take leave beginning April 1, 1948 to participate in a research program started by Dr. H. Urey at the University of Chicago. Among other things the program hopes to determine the temperatures of the environments in which fossil marine animals lived by studying the isotope ratios of the oxygen in the skeletons.

F. W. Rolshausen of the Humble Oil and Refining Company is studying environmental conditions during the deposition of several formations in the ancient Gulf of Mexico. He states:

> "Samples from many wells and outcrops have been studied in the area surrounding the Gulf of Mexico. The study of these samples shows that the deposits of any one formation have a highly variable composition from the Rio Grande to Florida. ..... In general the Gulf Coastal region can be divided into five major areas of deposition. The deposits are gradational between areas, and their boundaries are indefinite. These areas are: (A) South Florida; (B) North Florida, South Georgia and Southern Alabama; (C) Mississippi Embayment; (D) East Texas Basin; (E) Rio Grande Embayment. The contemporaneous deposits of fossiliferous and non-fossiliferous sands and shales, red beds, chalks, limestone, dolomites, anhydrite and salt, to a large extent seem to be dependent on the amount of rainfall on the land areas surrounding the ancient Gulf of Mexico. West of the Appalachian Mountains, during Lower Cretaceous and up to and including Eagle Ford times, the major source of sediments seems to be from rivers entering the Gulf from the north and northeast, and from the northwest and west on the east side of these mountains. After Eagle Ford times, the major source of sediments was from rivers entering the Gulf from the west. These rivers probably drained the major portion of the western part of the present Mississippi River basin. There is evidence that an ancient Rio Grande was the major source of sediments during late Upper Cretaceous, Eocene, Oligocene and Lower Miocene, and that the Mississippi River contributed very little to the sediments of the Gulf region until late Upper Miocene times."

Dr. L. W. Stephenson of the U. S. Geological Survey is completing his comprehensive report of the Upper Cretaceous Woodbine formation of Texas.

Dr. Parker D. Trask of the U. S. Geological Survey, Fred B. Phleger, Jr. of Amherst College, and Henry C. Stetson of the Museum of Comparative Zoology, Cambridge, Mass., report as follows on their ecological studies carried on in

the Gulf of Mexico in the ATLANTIS, the oceanographic research vessel of the Woods Hole Oceanographic Institution:2/

"The ATLANTIS spent the months of February and March 1947 in the northwest part of the Gulf of Mexico, primarily for the purpose of investigating the environmental conditions of deposition of sediments. The expedition was sponsored jointly by the Woods Hole Oceanographic Institution and the Geological Society of America. The latter contributed a grant of $14,500 for this purpose....., while the Oceanographic Institution supplied the vessel, crew, and scientific personnel for the expedition and made available laboratory facilities and personnel for working up the results.

"Despite considerable rough weather, the expedition was remarkably successful. Some 550 short cores of the bottom sediments, ranging in length from 5 to 50 cm., and 100 long cores, ranging in length from 1.5 to 3.3 m., were collected. Twelve lines of samples transverse to the coast across the continental platform from the mouth of the Rio Grande to the mouth of the Atchafalaya River, and 7 lines across the continental slope out to the deepest part of the Gulf, were taken. In addition, about 100 stations were occupied for plankton tows, serial temperature, and samples of water. Several hundred temperature-depth records were made with a bathythermograph along the lines of traverse, and continuous depth records were made with a recording fathometer. The material collected is now being actively worked up at the Woods Hole Oceanographic Institution. The U. S. Bureau of Mines Experimental Station at Pittsburgh, Pennsylvania, through the courtesy of H. M. Cooper, supervising chemist of the Coal Analysis Section, is cooperating in this work by making analyses of the organic content of the sediments."

WESTERN UNITED STATES

Mr. John Q. Burch of Los Angeles, California, Editor of the Proceedings of the Conchological Club of Southern California, has announced as a program for 1947 the completion of the discussion of the Amphineura, the final section of the extremely useful "Distributional List of the West American Marine Mollusks from San Diego, California to the Polar Sea."

OUTSIDE THE UNITED STATES

K. O. Emery of the University of Southern California is studying sediments collected from the Ranger Bank, a structure located at the edge of the continental shelf off Mexico about 200 miles south of San Diego. The bank measures 15 by 2 to 4 miles and is flat-topped, the shallowest depth being 67 fathoms. It is floored with outcropping metamorphic, volcanic, and sedimentary rocks probably mostly Miocene in age, patchily covered by a few inches of residual organic and authigenic sand. Phosphorite nodules are abundant, possibly derived from Miocene beds. Apparently, erosion by past wave action produced the flat top and left a

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2/ A preliminary report giving the above and additional information as this project appeared in SCIENCE, vol. 106, pp. 460-461, Nov. 14, 1947.

thin veneer of sand and rounded gravel. After submergence of the bank there has been a slow accumulation of coarser sand composed of organic remains, largely foraminiferal tests, and of glauconite which occurs mostly as internal casts of Foraminifera. Present wave motion and currents are strong enough to prevent the deposition of fine muds and to produce faint oscillation ripple marks on the sand, but they are not strong enough to roll cobbles, consequently cobbles and boulders are covered by encrusting organisms.

Operation Crossroads, Marshall Islands

During a resurvey of Bikini Atoll carried out during 1947, Dr. R. Dana Russell dredged the outer slopes and the lagoon. He reports as follows:

"Twenty-four dredging hauls on the outer slopes of the reef and five on coral heads in the lagoon were made during the Bikini Resurvey. These dredgings show that the outer part of the reef is a typical talus slope, covered with large blocks of limestone broken off by waves from the edge of the reef. The size of these blocks apparently decreases with depth. Occasional ones near the surface appear to weigh several tons, as a dredge attached by a one-inch chain to a half-inch steel cable was lost by breaking of the chain, after hooking on a large block. Blocks weighing several hundred pounds extend to more than 2000 feet, as a 5/32-inch stainless-steel airplane cable, carrying a small dredge, was broken when the dredge became caught at a depth of about 350 fathoms. The behavior of the dredges during the hauls, however, indicates that large blocks are rare below about 200 fathoms, the bottom consisting chiefly of boulders of limestone with sand areas between.

"Calcareous sand, consisting of remains of Halimeda, large Foraminifera, mollusk shells, and ground-up coral and algal material fills in the spaces between the blocks from the edge of the reef to depths of at least 600 fathoms. The amount of sand, relative to the larger fragments, increases with depth.

"From 50 feet (the shallowest dredging on the reef slope) to about 500, living corals, algae, Bryozoa, sponges, and other forms of marine life are present in abundance. The profusion and variety of life rapidly decreases with depth, however, and below 500 feet the predominant forms are Foraminifera, algae, a few deep-water corals, sponges, and brachiopods. Dredging No. 30, off Enyu Channel in 700 feet of water, brought up a number of delicate branching corals, sea fans, sponges, and a starfish. This haul was in marked contrast to most of those taken at this depth; which characteristically consisted of rounded white cobbles, boulders, and blocks of limestone with little living material."

H. S. Ladd and J. I. Tracey of the U. S. Geological Survey and Gordon Lill of the Office of Naval Research report that 5 holes totaling 4510 feet were drilled on Bikini Island. The deepest of these was carried to 2556 feet which is the deepest hole yet drilled on a Pacific coral island. No materials other than calcareous sediments--beach rock, reef limestones, coral rubble, and sand--were encountered. Preliminary studies of the corals by J. W. Wells and the mollusks by H. S. Ladd show that a late Tertiary fauna was encountered at 930 feet. Many of the species differ from those now living in the Marshall Islands,

some being new, others identical with forms occurring in the late Tertiary of the East Indies. The corals and mollusks together with Foraminifera and echinoids suggest a depth considerably shallower than that where they are now found. A number of the mollusk shells show original luster and traces of color pattern but other fossils show evidence of wear. It seems unlikely, however, that they were transported appreciable distances either horizontally or vertically. Larger Foraminifera from levels below 1020 feet have been identified by W. Storrs Cole as Lower Miocene, probably to be correlated with Tertiary e of the East Indian Section.

Thomas S. Austin of the Hydrographic Office and Thomas F. Goro carried on ecological studies which are summarized by Mr. Austin as follows:

"Opportunity was provided by the Special Weapons Division, U. S. Navy, for further ecological studies of the reefs and waters of Bikini Atoll. These studies, conducted during the recent Bikini Scientific Resurvey, July - September 1947, were in many respects similar to those made during the original survey in 1946.

"The investigations concerned with the reefs may be divided into two phases, the first dealing with the reef flat and the second with the numerous tide pools or solution basins along the island margins of the seaward reef. Along the reef flat in a portion of the reef between islands stations were selected near the seaward and lagoon margins of the reef. These stations were so selected that even at low tide there was a continuous flow of water. The movement of water across the windward reefs, whether ebb or flood tide, is always from east to west or from the ocean into the lagoon. Observations were taken at these selected points on the reef every three hours for periods varying from 24 to 48 hours. Temperature, depth and velocity data were recorded and samples taken for oxygen, pH, titratable base and salinity analyses. Semi-quantitative measurements were made of the total area of the reef flat so that areal productivity, heat exchange, carbonate deposition and other factors may be calculated.

"Four tide pools were chosen at the inner margin of the reef along the southeastern side of Bikini Island. Each of these selected pools has certain characteristics. One, the lowest, was isolated from the oceanic circulation only during very low tide and thus the water retained in the pool had little opportunity to undergo diurnal changes of any magnitude. Each of the other three pools was isolated for successively longer periods with pool number four, nearest the beach, being flushed only at very high tide or during periods of high surf. Each of these pools was sampled every three hours for several forty-eight hour periods. Measurements were made of the temperature, depth of water, salinity, oxygen, pH and titratable base. Several bottom sediment cores were taken from each of the pools. These have been sent to Dr. K. O. Emery for study.

"The diurnal variations in temperature, oxygen and salinity are very similar to those reported last year. The diurnal changes in pH, which were not studied during the 1946 Survey, are interesting. In the tide pools, the range in pH was from 8.0 (0400) to 9.3 (1600) while on the reef flat the diurnal range was from 7.95 (0500) to 8.35 (1400). The exact values for the titratable base cannot be given until the salinity

analyses have been completed and further calculations made. Both the pH and the titratable base values were obtained with the Beckman Meter.

"A series of samples were taken at selected locations in the lagoon and at one station several miles east of the seaward reef. In the lagoon, samples were taken at the surface and one meter above the bottom while in the open ocean, various depths to 150 meters were sampled. Routine oceanographic analyses were made on these samples, namely, temperature, salinity, oxygen, pH and titratable base.

"Unfortunately at this writing very little of the data is in a form ready for study. A report discussing the results of these investigations will be completed early in 1948. A short paper discussing the organic productivity of an atoll will be included in the symposium on Bikini to be published by the American Geophysical Union."

Fenner A. Chase, Jr. and F. M. Bayer, of the Division of Marine Invertebrates, U. S. National Museum, are revising the crab genus Trapezia and compiling data on the correlation of the distribution of the species with that of their coral hosts. A large collection of the crabs and host corals, with extensive field and color notes, was made by Mr. Bayer in connection with the 1947 Bikini resurvey.

Prof. Robert W. Hiatt of the University of Hawaii spent nearly a month on the island of Yap during the summer of 1946. Subtidal areas were explored by diving and thousands of marine invertebrates were collected for preservation and shipment to the University. These collections will be compared with material from the Philippines and Indo-China to the west and along the Great Barrier Reef of Australia to the south to obtain information about the dispersal of species from the Asiatic mainland into the Pacific.

Work of the Hydrographic Office, Navy Department

Observations on the occurrence of "discolored water" which is usually due to the presence of plankton organisms have been received by the Hydrographic Office since the late 1800's. These observations, made primarily by personnel aboard vessels of the Merchant Marine, both American and foreign, have been plotted on a worldwide basis. The resulting chart shows a most interesting distribution of the phenomena both as to frequency and as to geographical distribution of specific colors such as red, yellow and green. A study has been initiated of the distribution of such organisms.

Naval expeditions to the Arctic, NANOOK, and to the Antarctic, HIGHJUMP, collected bottom samples and obtained associated temperature and salinity data. The Hydrographic Office continued its long-range program of collecting and charting oceanographic soundings, thereby contributing to the knowledge of the ocean's bottom. A bathymetric chart of the Philippine Sea Area from Korea to New Guinea, H.O. 5485, was published as one of a projected series of the contour charts of the world.

Dr. H. H. Hess3/ of Princeton University who was associated with the Hydro-

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3/ Hess, H. H., Drowned ancient islands of the Pacific Basin: Am. Jour. Sci., vol. 244, no. 11, pp. 772-791, 1946.

graphic Office during the war, published an account of a newly recognized form of flat top seamount or drowned islands which proved to be fairly common in the Central Pacific and to which the generic name "guyot" was given.

The Hydrographic Office has initiated a long-range program for the collection of hydrographic and oceanographic observations to be made by personnel aboard naval, Merchant Marine, and private vessels. Although the primary purpose of these observations is to collect basic data to be utilized during the preparation of charts, manuals and other publications issued by the Hydrographic Office, considerable information of interest to marine ecology will result. For example, a Special Observers Log has been prepared for the recording of these data. This log, set up in such a manner that the resulting data can be transferred to IBM punch cards, requests observations pertaining to discolored water (color, cause, and extent), frequence (frequency, distribution, and causative organisms), birds (type and number), whales (type and number) and the type and number of large animals exclusive of whales. In addition to these biological observations, data are requested for various meteorological and oceanographic phenomena, these data to be recorded simultaneously with the biological observations. Thus, when sufficient information is available estimations of the correlation between geographical distribution and frequency of the biological phenomena and the associated environmental factors may be attempted. As data such as these may be of considerable value to National Defense, especially during a national emergency, it is hoped that interested activities will request copies of the Special Observers Log for use during routine and special operations at sea. Following the completion of these operations, the forms should be sent to the Hydrographic Office for inclusion in their files. Once these data have been received in sufficient quantity to be statistically significant and have been properly processed and filed, it is planned that some mechanism will be set up whereby the basic information of an ecological nature may be made available to those activities interested in some problem or problems concerned with marine ecology.

The book, Wind Waves at Sea; Breakers and Surf, by Dr. H. B. Bigelow and Dr. W. T. Edmundson was published as Hydrographic Office Publication No. 602 during the year. This volume, the first popular work on the subject in more than ten years, incorporates much of the knowledge acquired during the extensive wartime research into waves and the surf zone as well as observations made by thousands of seafarers during the past century. Detailed discussions of such subjects as the physical nature, height, steepness, and contours of wind waves, as well as current and shoal water effects, are included. Other sections of the book describe the alteration of seas into swells, the frequency with which various roughnesses of the sea surface occurs throughout the world, the causes and alterations of surf, and the relation the direction and height of breakers bear to the shape of the coast. The treatment throughout the publication stresses the quantitative relationships existing between waves and the envionments in which they develop, decay, and change into breakers. As both authors are marine zoologists of high caliber, it is only natural to find that the text incorporates much that is of value to the marine ecologist in interpreting effects wrought by physical phenomena in the archi-benthic and littoral zones.

The United States Geological Survey is completing the detailed survey of Okinawa mentioned in last year's report. Similar work has been started in Palau and on Yap and will include some work on the existing coral reefs of these areas.

Brief Summary of Albatross Expedition

Between Martinique and the Canal Zone, the Swedish Deep Sea Expedition was host to Dr. Fred B. Phleger, Jr., a representative of the Hydrographic Office and the Woods Hole Oceanographic Institution. Under the personal direction of Professor Hans Pettersson, Director of the Oceanografiska Institutet at Goteborg, Sweden, this expedition is embarked aboard the 1,400 ton motor schooner ALBATROSS for a fifteen month world cruise. The itinerary includes Madeira, Canal Zone, Galapagos Islands, Hawaii, Tahiti, and the Netherlands East Indies before returning to the Mediterranean through the Indian Ocean.

As it is the purpose of the cruise to investigate the deep ocean bed and its deposits, Dr. Phleger demonstrated special towing techniques devised for collecting living Foraminifera and also loaned the party a new type of bottom sampler. New Swedish oceanographic instruments and techniques are acquiring extremely important data hitherto unavailable. The most important of these new developments is the Kullenberg coring tube which obtains cores up to 20 meters in length at depths of 5,000 meters or more. Scarcely less important are measurements of apparent thicknesses of oceanic sediments using seismic methods developed by Weibull and the continuous, large-scale depth records being obtained from new, powerful echo-sounding apparatus developed by Marine Instruments, Ltd., which is capable of obtaining records to at least 7,500 meters depth. Standard oceanographic stations are occupied frequently, with determinations being made for contents of chlorinity, oxygen, uranium, radium, etc. in the water samples. In addition, closely spaced bathythermograph lowerings are made, and the Hydrographic Office's Special Observer's Log is being kept for reporting occurrences of discolored water, phosphorescence, and concentrations of whales, other large sea animals, and birds.

RECENTLY PUBLISHED PAPERS

Most of the papers listed below appeared during the year ending May 1, 1947.

GENERAL

Backlund, Helge O.
Wrack fauna of Sweden and Finland, Ecology and Chorology: Opuscula Entomologica Supplementum, pp. 1-236, Lund (Sweden), 1945.

Bramlette, M. N.
The Monterey formation of California and the origin of its siliceous rocks: U. S. Geol. Survey Prof. Paper 212, pp. 1-57, 1946.

Bridge, Josiah
(and Barnes, Virgil E. and Cloud, Preston E., Jr.). Stratigraphy of the Upper Cambrian Llano Uplift, Texas: Geol. Soc. America Bull., vol. 58, pp. 109-124, 1947.

Clarke, George L.
Dynamics of production in a marine area: Ecol. Monographs, vol. 16, no. 4, pp. 321-335, 9 figs., 1946.

Application of concepts necessary in evaluating dynamics of production applied to Georges Bank with a consideration of the quantitative relationships (J. W. Hedgpeth).

Coe, Wesley R.
The means of dispersal of bathypelagic animals in the North and South Atlantic Oceans: Am. Naturalist, vol. 80, pp. 435-469, 1946.

Coker, R. E.
This great wide sea: Univ. of North Carolina Press, pp. 1-135, 91 pls., 23 figs., 1947.

Colman, John
Marine biology at St. Helena: Proc. Zool. Soc. London, vol. 116, pp. 266-281, 1946.

Crespen, B. A.
Note on the age and paleogeography of the Brown Coal Deposits of Gippsland, Victoria: Proc. Roy. Soc. Victoria, vol. 57 (N.S.), pp. 49-56, 1945.

Dexter, Ralph W.
The marine communities of a tidal inlet at Cape Ann, Massachusetts: a study in bio-ecology: Ecol. Monographs, vol. 17, pp. 261-294, 1947.

Du Rietz, G. Einar
Wellengrenzen als ökologische Aquivalente der Wasserstandslinien: Zool. Bidrag Uppsala, vol. 25, pp. 534-550, 8 figs., 1947.

The author extends the concept of the littoral or intertidal zone to include the upper limits of the storm waves on marine and lacustrine shores. In place of littoral, the term amphibiontic belt is reiterated from a

previous paper, and two secondary terms are proposed for the divisions of this belt: the geoamphibiontic belt, the zone of periodically submerged land organisms, and hydroamphibiontic belt for the zone of periodically emerged water organisms. The best indicator for the upper limit of the hydroamphibiontic belt on the Swedish coast is the occurrence of Balanus balanoides. (J. W. Hedgpeth.)

Ekman, Sven

Uber die Festigkeit der marinen Sedimente als Factor der Tierverbreitung, ein Beitrag zur Associationsanalyse: Zool. Bidrag Uppsala, vol. 25, pp. 1-20, 10 figs., 1947.

The consistency of bottom sediments influences the density of populations of bottom living organisms and alters the character of the animal communities concerned. The differentiation of two bordering animal communities as separate associations is only justified if their inner continuity is greater than their respective differences. (J. W. Hedgpeth).

Emery, K. O.

1. Marine solution basins: Jour. Geology, vol. 54, no. 4, pp. 209-228, 1946.

2. Submarine geology of Bikini Atoll, (Abstract): Geol. Soc. America Bull., vol. 57, no. 12, pt. 2, p. 1191, 1946.

Gillette, Tracy

The Clinton of western and central New York: New York State Mus. Bull. 341, pp. 1-191, 1947.

Glaessner, Martin F.

Principles of micropalaeontology: John Wiley & Sons, 1947.

Gunter, Gordon

1. Paleoecological import of certain relationships of marine animals to salinity: Jour. Paleontology, vol. 21, no. 1, pp. 77-79, 1947.

2. (and Smith, F. G. Walton and Williams, Robert H.). Mass mortality of marine animals on the Lower West Coast of Florida, November 1946-January 1947: Science, vol. 105, pp. 256-257, 1947.

Hansen, Kaj

Investigations of the geography and natural history of the Præstø Fjord, Zealand, no. 1, Introduction and the bottom deposits, pp. 1-46, 1944.

Hayasaka, Ichero

Is there any particular feature in the marine Neogene fauna of Taiwan?: Bull. Oceanographical Institute of Taiwan, no. 2, pp. 21-32, 1947.

Heegaard, P.

The bottom fauna of Præstø Fjord: Folia Geographica Danica, Tom. III, no. 3, pp. 59-82, 1944.

Hess, H. H.

Drowned ancient islands of the Pacific Basin: Am. Jour. Sci., vol. 244, no. 11, pp. 772-791, 1946.

Hewatt, Willis G.
Marine ecological studies on Santa Cruz Island, California: Ecol. Monograph vol. 16, pp. 185-210, 1946.

Howell, B. F.
(and Hale, H. E., II). Fossiliferous pebbles in "Pensauken Gravel" at Princeton, New Jersey: Jour. Geology, vol. 54, no. 6, pp. 386-390, 1946.

Hutchins, Louis W.
The bases for temperature zonation in geographical distribution: Ecol. Monographs, vol. 17, pp. 325-335, 1947.

Jensen, Aage J. C.
The hydrography of Præstø Fjord: Folia Geographica Danica, Tom. III, no. 2, pp. 47-58, 1944.

Johnson, J. Harlan
Nubecularia from the Pennsylvanian and Permian of Kansas: Jour. Paleontology, vol. 21, no. 1, pp. 41-45, 1947.

Jutting, W. S. S. van Benthem
Marine organisms in the island of Walcheren (Netherlands) during the inundation, Oct. 1944-Oct. 1945: Archief, Uitzegeven door het Zeewosch Genootschap der Wetenschappen, pp. 1-7, 1946.

Ketchum, Bostwick H.
The biochemical relations between marine organisms and their environment: Ecol. Monographs, vol. 17, no. 3, pp. 309-315, 5 figs., 1947.

Kuenen, Ph. H.
Rate and mass of deep-sea sedimentation: Am. Jour. Sci., vol. 244, no. 8, pp. 563-572, 1946.

Lechevalier, Paul
Contribution à l'étude de la répartition actuelle et passée des organismes dans la zone néritique: Société de Biogéographie, Mém., Vol. 7, 434 p., 29 figs. and tables, 9 pls., 1940; 1947.

Contents:

Legendre, Renée
Le milieu marin océanique, néritique et littoral, pp. 1-16, 2 figs.

General discussion of the distribution and subdivisions of the oceanic masses, their physical and biological characters.

Fontaine, Maurice
A propos de l'action de la lumière et en particulier des rayons ultra-violets sur la répartition des organismes dans la zone néritique, pp. 17-22.

Summary of present state of knowledge of relations between distribution of organisms and radiation, especially in the Ultra-violet band.

Faye, Louis
Le plateau continentale et la métamorphose des poissons, pp. 23-29.

The importance of the configuration of the continental shelf from the point of view of possibilities of renewing its economic population.

Bigot, A.
Faunes néritiques du Jurassique inférieur de la normandie, pp. 31-39.

Survey of present-day sedimentary and ecologic conditions in the neritic zone of the Norman coast and their significance in the interpretation of sedimentary conditions and character of the faunas of the Norman Lower Jurassic,--faunal autochthones and concentrations, "hard grounds", etc.

Dechaseaux, Colette
Répartition des lamellibranches dysodontes au Jurassique, dans l'est du bassin de Paris, pp. 41-54, 5 figs.

Deduction of shifts in ecologic conditions during the Jurassic from observed relationships in the distribution of dysodont pelecypods. The deposits were all formed in a shallow sea in which changes in depth were feeble but nevertheless sufficient to be reflected by bivalve populations.

Abrard, Renee
Répartition géographique et migrations des orbitoides, pp. 55-73.

Summary, by geologic periods and epochs, of the geographical distribution and evolution of the orbitoid Foraminifera.

Lemoine, Mme. P.
Les algues calcaires de la zone néritique, pp. 75-138.

Perhaps the best recent systematic discussion of the ecology of the geologically important calcareous algae, although "stromatoliths" are not included. Important bibliography.

Seurat, L. G.
La répartition actuelle et passée des organismes de la zone néritique de la Mediterranée nord-africaine (Algérie-Tunisie), pp. 139-179, 8 figs.

Physical conditions in the Mediterranean; its fauna; relations with the Red Sea and the Atlantic; neritic plankton; analysis of biocoenoses of the neritic zone of the Algerian-Tunisian coasts. Little reference to geologic record of the area.

Feldmann, Jean
La végétation benthonique de la Mediterranée, pp. 181-195.

Analysis of the marine floral biocoenoses of the subdivisions of the Mediterranean neritic zone. In general they have the character of tropical seas, such as the West Indies, rather than more boreal areas.

Burollet, P. A.
Note sur la zone néritique du Maroc atlantique, pp. 197-203.

Results of preliminary investigations of the ecology of the neritic zone of the Moroccan Atlantic coast.

Davy de Virville, A.
Les zones de végétation sur le littoral atlantique, pp. 205-251, 1 table, 7 pls.

Analyses of 14 zones of marine algae in the Gulf of Gascony. He suggests that plants should be preferred to animals in characterizing the littoral zones because of their lack of mobility.

Prat, H.
Observations bionomiques sur les rivages atlantiques de l'Amérique du Nord et les îles voisines, pp. 254-278.

Comparative bionomic analyses of the neritic zones of the Bermuda Islands and the Gulf of St. Lawrence.

Fischer, P. H.
Notes sur les peuplements littoraux d'Australie.
I. Influence des courants chauds sur la vie littorale en Australie temperé, pp. 279-288, 2 figs.
II. Sur le peuplement des roches intercotidales en Australie temperé, pp. 289-313, 5 figs.
III. Sur la faune de la mangrove australienne, pp. 315-329.

Andre, Marc
La faune acarologique du système littoral, pp. 331-345.

Berland, Lucien
Les araignées marines, pp. 347-353.

Timon-David, Jean
Observations sur la faune dipterologique littoral des îles du Golfe de Marseille, pp. 355-361, 1 fig.

Germain, L.
(and Fischer-Piette, E.). La faune benthique du plateau continentale et les méthodes statistiques, pp. 363-377.

Discussion of methods of analyzing distribution of marine organisms by adding quantitative data to qualitative information.

Schenck, H. G.
(and Keen, A. M.). Biometrical analysis of molluscan assemblages, pp. 379-392, 2 figs., 2 pls.

Determination of distributional zones of American West Coast mollusks by biometrical means.

Fischer-Piette, E.
Sur quelques progres recents et sur les méthodes et tendances actuelles, en bionomie intercotidale. (Substratum rocheux, regions tempérées), pp. 393-434.

Survey of development, methods, and present status of ecological studies in the areas indicated, with extensive bibliography covering the period, 1929-1939.

Each of the articles listed above contains a useful list of references. (John W. Wells).

Lowman, Shepard W.
Fundamental research in sedimentology: Am. Assoc. Petroleum Geologists Bull., vol. 31, no. 3, pp. 501-512, 1947.

Lowenstam, H. A.
(and DuBois, E. P.). Marine Pool, Madison County, a new type of oil reservoir in Illinois: Illinois Geol. Survey, Rept. of Investigations, no. 114, pp. 1-30, 1946.

Lundblad, O.
Markonesien und Atlantis. Eine historisch-biogeographische Ubersicht: Zool. Bidrag Uppsala, vol. 25, pp. 201-323, 20 figs., 1947.

A review of the literature on Atlantis and Macronesia, with survey of many papers on animal distribution which bear on the problem, with an index of the authors cited. (J. W. Hedgpeth).

Ma, Ting Yong H.
(and Hayasaka, Ichiro, and Kawaguchi, Shiro). Observations on the coral reefs of the Penghu Islands, Taiwan: Bull. Oceanographical Institute of Taiwan, no. 1, pp. 1-7, 1946.

McKee, Edwin D.
Experiments on the development of tracks in fine cross-bedded sand: Jour. Sed. Petrology, vol. 17, no. 1, pp. 23-28, 1947.

Nelson, Thurlow C.
Some contributions from the land in determining conditions of life in the sea: Ecol. Monographs, vol. 17, no. 3, pp. 337-346, 7 figs., 1947.

A discussion of the role of tidal flats in the food cycle of coastal waters. The author suggests that the decline of eelgrass may not have been the tragedy commonly supposed and criticizes the Danish conception of the oyster as a detritus feeder, suggesting that the bacteria on the decomposing detritus may be the actual food element. Eelgrass appears to be a competitor for the same elements that diatoms and dinoflagelattes need, and these latter are possibly more important to the economy of such species as the oyster than eelgrass. (J. W. Hedgpeth).

Owodenko, Boris

Memoire Explicatif de la Carte Geologique du Bassin Houiller de Djerada et de la Region au sud d'Oujda: Société Géologique de Belgique, vol. 70, pp. 5-168; 1 map. (Plate 1 is the Carte Géologique du Bassin Houiller de Djerada et de la Region au Sud d'Oujda /Maroc Oriental/), 1946.

The following stratigraphic Divisions have been made:

1. Primaire indetermine
2. Gothlandien
3. Devonien
4. Viseen supérieur
5. Namurien
6. Westphalien inferiur
7. Transition series from lower to upperWestphalien.
8. Westphalien supérieur
9. Trias
10. Lias
11. Dogger
12. Callovien-Oxfordien-Lusitanien
13. Kimmeridgien

Each series is discussed from the point of view of the lithology, thickness and sections, paleontology and paleogeography. The paleogeography is expanded to include the conditions of sedimentation and commonly, inferences from the fauna. The Paleozoic and Mesozoic seas were, for the most part, epicontinental and the faunas inhabiting them were widespread. Graptolites are common in the Gothlandian and the Devonian and some of the Gothlandian graptolites have been found reworked in the Viseen. Brachiopods abound in the upper Paleozoic and Ammonites in the Mesozoic. The dolomitization of the limestones, especially in the Lias, presents a major problem. Owodenko maintains that the absence of limestones free from algae is due to their dolomitization and that the calcareous algae play a very important role in the process of much of the dolomitization. Terriginous sediments were more important during the Dogger than during the Lias. The fauna is neritic but the sea must have been deeper than during the Lias because of the great abundance of the Ammonites. The ferruginous oolite at the close of the Dogger indicates by its uniformity, equable conditions; the seas were relatively rich in $CaCo_3$, of uniform depth, and influenced by current action. The Callovian includes a large percentage of clay and a large Ammonite fauna indicating relatively deep seas but, on the other hand, the sandy lenses, sporadic conglomerates and oolitic limestone indicate epicontinental conditions. The loose sands with Lithodomus burrows and Trigonia could have been deposited only near the mouth of a river. (Julia Gardner). /See footnote on page 68./

Price, W. Armstrong

(and Elias, Maxim K., and Frye, John C.). Algal reefs in cap rock of Ogallala formation on Llano Estacado Plateau, New Mexico and Texas: Am. Assoc. Petroleum Geologists Bull., vol. 30, no. 10, pp. 1742-1746, 1946.

Roughley, T. C.

Wonders of the Great Barrier Reef: Charles Scribner's Sons, New York, pp. 1-274, 52 natural color photographs, 1947.

Shepard, Francis P.

1. Submarine geology studies in the Pacific: Am. Assoc. Petroleum Geologists Bull., vol. 31, no. 1, pp. 178-180, 1947.

2. (and Emery, K. O). Submarine photography off the California coast: Jour. Geology, vol. 54, pp. 306-321, 1946.

Smidt, E. L. B.
The effects of ice winters on marine littoral faunas: Folia Geographica Danica, Tom. II, no. 3, pp. 1-36, 1944.

Stephenson, T. A.
1. The constitution of the intertidal fauna and flora of South Africa, Part III: Ann. Natal Mus., vol. 11, no. 2, pp. 207-324, 11 figs., pls. XV, XVI, 1947.

This is the concluding paper of the general series on the South African intertidal region, and includes a bibliography of the South African intertidal survey and of other important papers on the marine fauna and flora of South Africa. A large part of the paper is given over to an evaluation of Ekman's Tiergeographie des Meeres, and the place of South Africa in Ekman's system. Similarities between the South African coast and that of Pacific North America, based on Ricketts and Calvin's Between Pacific Tides, are pointed out. The paper concludes with a list of the marine algae identified from the South African coast. (J. W. Hedgpeth).

Stetson, Henry C.
(and Phleger, Fred B., Jr.). Oceanography as related to petroleum geology: Am. Assoc. Petroleum Geologists Bull., vol. 31, no. 1 pp. 175-178, 1947.

Stewart, Ralph
Geology of Reef Ridge, Coalinga district, California: U. S. Geol. Survey Prof. Paper 205-C, pp. 79-115, 1946.

Suzuki, Koichi
(and Takai, Fuyuji). The fossil beds in the vicinity of Tako-Cho, Katori-Gun, Chiba-Ken: Geol. Soc. Japan Jour., vol. 42, no. 496, pp. 1-35, 2 figs. including sketch map, January 20, 1935. In Japanese; abstract, Japanese Jour. Geology and Geography, vol. 12, nos. 3-4, pp. 25-26, October 1935.

The discovery of a mammoth's tusk near Tako inspired the investigation in the area. The Pliocene has received a triple division: tuffaceous sand, tuffaceous shale and sandy tuff. The tuffaceous shale is the possible equivalent of the Togane bed in which the mammoth remains were discovered and is presumably of upper Pliocene age. The relationship of the Pliocene and Pleistocene in the Boso Peninsula east of the Chitsu River is not yet established, but in any case, the Tako shell beds are referred to the lower Pleistocene.

In Tako-Cho, the Pleistocene is represented by unstratified sand interbedded with lenticular gravel. The sand is, for the most part, fine grained; the color is gray to bluish gray to yellowish brown. A good invertebrate fauna was collected and some of the shell beds are several meters thick.

Several assemblages have been identified. No. 1 assemblage is from a remarkably continuous shell bed. Most of the shells are endemic Japanese species. Species commonly associated with the Kuroshio or Black Current type are nearly equal in numbers to those of the Oyashio or Kurile Current

type. Furthermore, those species most commonly associated with the Black Current, are characteristic of it while those of the Kurile Current type are, with the exception of Chlamys swifti, rather widely distributed in areas governed by warmer currents. The assemblage closely resembles the fauna living along the outer coast of the Boso Peninsula. The abundance of Gomphina indicates proximity to the beach line.

No. 2 assemblage, unlike No. 1, is represented by small isolated biotas. Like No. 1, however, the species are, for the most part, endemic and those commonly associated with the Black and Kurile Currents, though not restricted to them. The fauna most closely resembles that living on the Pacific Coast of Chiba and Ibaraki Prefectures. The littoral genera, Gomphina and Sunetta are absent indicating deposition farther off shore than the area in which No. 1 was laid down.

The character of the sand which has yielded assemblage No. 3 is similar to that of No. 1 but unlike No. 1, the fossils do not form a continuous shell bed but are clustered in small associations. The most common species, such as Pecten and Nassarius, are of medium size and constitute a faunule more closely related to No. 1 than to No. 2. However, like both Nos. 1 and 2, the greater number of species are endemic and Black and Kurile Current species are almost equally well represented. The temperature of the sea water and other conditions were probably about the same in the 3 faunas. However, Gomphina and Sunetta are absent and probably, No. 3 was laid down farther off shore than No. 1 but possibly not so far out as No. 2.

No. 4 assemblage is from a sand similar to that containing No. 1 and is composed, for the most part, of a few abundant species including Glycymeris vestita and Ostrea gigas which are common also in Nos. 1 and 2. The dominant forms in No. 4 are endemic Japanese species and characteristic Black Current species; there are no Kurile Current elements. Gomphina is absent and Sunetta is rare. The association shows a slightly brackish tendency but the temperature was probably about the same as in Nos. 1 to 3 and the depth about the same as that of No. 3.

No. 5 assemblage seems to be a mixture of at least two other associations, one a shallow marine biota similar to Nos. 1 and 4, and the other a fresh water assemblage represented by one or more species of Erodona and Corbicula. The shallow water elements in the fauna include endemic species and some characteristic Black Current species but none indicating a Kurile current fauna. The temperature of the water was probably a little higher than that in which Nos. 1 to 4 associations lived. The presence of Erodona and Corbicula suggests the proximity of fresh water but the absence of Gomphina and Sunetta is indicative of deposition slightly off shore. The assemblage is similar to that off Boso Peninsula.

The fossils from Locality No. 7, 15 meters below the surface, in a well excavated at Ino, are all minute. No classification has yet been made. The temperature may have been a little higher than that in which the other biotas lived.

A total of 203 species has been recognized in the Tako shell beds, 151 of them, determined: 124 or 82.1 percent of the determined species are living.

The apparent stratigraphic sequence of the associations is as follows:

Uppermost fossil zone	No. 3 assemblage
Upper fossil zone	No. 5 assemblage
Middle fossil zone	No. 2 assemblage
Lower fossil zone	No. 1 assemblage
Lowermost fossil zone	Assemblage from Locality 7

An attempt has been made to correlate the Tako biotas. The relation of the No. 1 association to the Yanabe shell bed seems very close. A comparison is also made of the Tako and Semata faunas both of which contain a large number of endemic species. In the Semata shell bed, however, the Kurile Current element is comparatively strong and the Black Current influence relatively weak. A relationship is also obvious with the faunas of the Matsuzaki and Kinoshita stages of the Narita formation. There is some doubt about the stratigraphic relation between the Yanabe bed and the Narita outcrops and about the relation of both of those shell beds to the faunas from the Tako localities. (Julia Gardner). [See footnote on page 68.]

Tchernov, A. A.

Sur la question de l'extinction des organismes: Bull. Soc. Naturalistes de Moscou, No. Ser., t. 51, pp. 1-14, 1946 (Russian with English summary).

Teichert, Curt

1. Stratigraphy of Western Australia: Jour. and Proc. Royal Soc. New South Wales, vol. 80, pp. 81-142, 1947.

2. Contribution to the geology of Houtman's Abrolhos, Western Australia: Proc. Linn. Soc. New South Wales, vol. 71, pts. 3-4, 1947.

3. (and Serventy, D. L.). Deposits of shells transported by birds: Am Jour. Sci., vol. 245, no. 5, pp. 322-328, figs. 1-2, May 1947.

Thorson, Gunnar

1. Technique and future work in Arctic animal ecology: De Danske Ekspeditioner til Østgrønland 1926-39, Appendix 4, Meddilelser om Grønland, udgivne af Kommissionen for Videnskabelige Undersøgelser i Grønland, Bd. 144, no. 4, pp. 1-40, 1946.

2. Reproduction and larval development of Danish marine bottom invertebrates, with special reference to the planktonic larvae in the sound (Øresund). (With a section on lamellibranch larvae by C. Barker Jorgensen): Medd. Komm. Dan. Fisk.-Havunders. Plankton, vol. 4, no 1, pp. 1-523, 198 figs., 1946.

This monumental treatise will be a standard reference for many years because of its excellence and the broad field it covers. There is a wealth of data and illustrations, and a 35 page bibliography which includes many titles in general marine ecology. (J. W. Hedgpeth).

Tracey, J. I.

(and Ladd, H. S., and Hoffmeister, J. E.). Reefs and islands of Bikini, Marshall Islands: Geol. Soc. America Bull., vol. 57, no. 12, pt. 2, p. 1238, 1946 (abstract).

Wilson, Douglas P.
They live in the sea: Collins, pp. 1-128, 1947.

Mainly a series of excellent photographs of various littoral invertebrates and fishes of the Plymouth area, with accompanying text. (J. W. Hedgpeth).

Woodring, W. P.
(and Bramlette, M. N., and Kew, W.S.W.). Geology and paleontology of Palos Verdes Hilles, California: U. S. Geol. Survey Prof. Paper 207, pp. 1-145, 1946.

Zo Bell, Claude E.
1. Marine microbiology, a monograph on hydrobacteriology: Chonica Pub. Co., Waltham, Mass., 1946.

2. Progress of studies relating to microbiology of sediments: Am. Assoc. Petroleum Geologists Bull., vol. 31, no. 1, pp. 180-181, 1947.

PLANTS

Brander, G.
Neue Beiträge zur Kenntnis der interglazialen Bildungen im Finnland: Finland Comm. Geol. Bull., no. 128, pp. 87-137, 5 figs., 1943.

A study of marine, brackish and fresh-water diatoms, marine silicoflagellates and tree pollens from a number of moraines and interglacial beds in Finland. Ecological data is presented, though not always stressed.

Chapman, V. J.
Marine algal ecology: Botanical Review, vol. 12, no. 10, pp. 628-672, 1940.

Davis, John H.
The peat deposits of Florida, their occurrence, development, and uses: Florida Geol. Survey Bull. No. 30, pp. 1-247, 1946.

Doty, Maxwell S.
Critical tide facots that are correlated with the vertical distribution of marine algae and other organisms along the Pacific coast: Ecology, vol. 27, no. 4, pp. 315-328, 1946.

Elias, Maxim K.
Fossil symbiotic algae in comparison with other fossil and living algae: Am. Midland Naturalist, vol. 30, pp. 282-290, 1946.

Fenton, Carroll Lane
Algae of the Pre-Cambrian and early Paleozoic: Am. Midland Naturalist, vol. 36, pp. 259-263, 1946.

Glock, Waldo S.
Algae as ecologic indicators: Am. Midland Naturalist, vol. 36, pp. 279-281, 1946.

Johnson, J. Harlan
Late Paleozoic algae of North America: Am. Midland Naturalist, vol. 36, pp. 264-274, 1946.

Lumiala, O. V.

Zwei Moorprofile aus Siilinjärvi, dem nördlichsten bekannten Fundort fossiler Trapa natans in Finnland: Finland Comm. Geol. Bull., no. 128, pp. 1-20, 2 figs., 1943.

Marine, brackish, and fresh-water diatoms from Siilinjärvi, Findland, and their depth, abundance, and ecological significance, are discussed in profiles of two moors, the Törönniitynsui, and the Mikansuo.

Mölder, Karl

1. Studien über die Ökologie und Geologie der Bodendiatomeen in der Pojo-Bucht: Finland Comm. Geol. Bull., no. 127, pp. v-vi, 1-202, 22 figs., 1943.

A study of the marine, brackish, and fresh-water diatoms from the bottom of Pojo Bay, Finland, presents much ecologic data regarding the changes in salinity between the head and mouth of the bay. The distribution of the diatoms during the Quaternary is obtained from borings.

2. Die postglaziale Klimaentwicklung im Lichte der fossilen Diatomeenfunde in Südfinnland: Finland Comm. Geol. Bull., no. 132, pp. 15-54, 17 figs., 1944.

The development of postglacial climate in south Finland, as shown by marine, brackish and fresh-water diatoms. The diatoms are particularly valuable where tree pollens are lacking or have doubtful significance.

3. Das karelische Eismeer im Lichte der fossilen Diatomeenfunde: Finland Comm. Geol. Bull., no. 132, pp. 55-85, 7 figs., 1944.

The character of the Karelian ice sea in Finland, which formerly linked the White Sea with the Baltic, is shown by an analysis of fossil marine, brackish, and fresh-water diatoms. At depths of 1.4 to 2.1 meters, the fossil flora is composed of 20 to 50% of marine species, the rest being fresh-water. At other depths down to 3.5 meters, a small percentage of brackish-water species occur mixed with the above.

Olsen, Sigurd

The vegetation in Præstø Fjord, 1. Spermatophyta and Charophyta: Folia Geographica Danica, Tom. III, no. 4, pp. 83-130, 1945.

Peck, Raymond E.

Fossil charophyta: Am. Midland Naturalist, vol. 36, pp. 275-278, 1946.

Salmi, Martti

Ein Seehundfund aus Ruukki und die Salzwasserkonzentrationsschwankungen des Wassers in dieser Gegendwährend der Postglazialzeit auf Grund fossilen Diatomeenfloren: Finland Comm. Geol. Bull., no. 132, pp. 165-187, 10 figs., 1944.

An extensive study of the fossil marine, brackish, and fresh-water diatom floras has indicated the variations of salt concentration in the vicinity of Ruukki, Finland, during postglacial time. A fossil seal found in the same beds is estimated to have become extinct about 6000 B.C.

Wilson, L. R.
The correlation of sedimentary rocks by fossil spores and pollen: Jour. Sed. Petrology, vol. 16, no. 3, pp. 110-120, 1946.

PROTOZOANS

Cushman, Joseph A.
(and Stainforth, R. M.). Foraminifera of the Cipero marl formation of Trinidad, British West Indies: Cushman Lab. for Foraminiferal Research Spl. Pub. 14, pp. 1-75, 1945.

Detling, Mildred Riechers
Foraminifera of the Coos Bay lower Tertiary, Coos County, Oregon: Jour. Paleontology, vol. 20, no. 4, pp. 348-361, 1946.

Hoglund, Hans
Foraminifera in the Gullmar Fjord and the Skagerak: Zool. Bidrag Uppsala, vol. 26, pp. 1-328, 32 pls., 312 figs., 2 maps, 7 tables, 1947.

Discusses 133 species in 13 families, taken by core sampler and other methods. Relative abundance and bathymetric distribution, based on counts from 72 core samples in Gullmar Fjord in 1927 and 32 in the Skagerak in 1937 are discussed. No ecological summation is presented since the taxonomy of many forms is still uncertain. (J. W. Hedgpeth).

Samoilova, R.
La distribution stratigraphique des foraminifères dans les depots des paléogene superieur de la rivière Alma en Crimée: Bull. Soc. Naturalistes de Moscou, n. ser., t. 51, pp. 40-57, 1946 (Russian with English summary).

Thalmann, Hans E.
1. Heterochthonous Foraminifers in Recent sediments (colluvial assemblages): Geol. Soc. America Bull., vol. 57, no. 12, pt. 2, pp. 1235-1236, 1946 (abstract).

2. Micropaleontology of Miocene Progreso formation, southwestern Ecuador: Geol. Soc. America Bull., vol. 57, no. 12, pt. 2, p. 1236, 1946 (abstract).

3. Fossil radiolarian beds of southwestern Ecuador: Geol. Soc. America Bull., vol. 57, no. 12, pt. 2, p. 1285, 1946 (abstract).

Wood, Alan
1. The supposed Cambrian Foraminifera from the Malverns: Quart. Jour. Geol. Soc. London, vol. 102, pt. 4, no. 408, pp. 447-460, 1947.

2. (and Barnard, T.). Ophthalmidium: a study of nomenclature, variation, and evolution in the Foraminifera: Quart. Jour. Geol. Soc. London, vol. 102, pt. 2, no. 406, pp. 77-113, 1946.

SPONGES

de Laubenfels, M. W.
Ecology of the sponges of a brackish water environment, at Beaufort, N. C.: Ecol. Monographs, vol. 17, no. 1, pp. 31-46, 2 figs., 1947. (also publ. as Bull. No. 4, Duke Univ. Marine Sta.)

The Brackish environment of Beaufort Harbor and vicinity inhibits sponge life below low tide, but there are five species which occur abundantly in the intertidal zone. These sponges are helped by currents and endure temperatures from zero to 33°C. They seem to thrive better in situations of partial illumination rather than full sunlight. (J. W. Hedgpeth).

Okulitch, Vladimir
Intervallum structure of Cambrocyathus amourensis: Jour. Paleontology, vol. 20, pp. 275-276, 1946.

COELENTERATES

Durham, J. Wyatt
Corals from the Gulf of California and the North Pacific Coast of America: Geol. Soc. America Mem. 20, pp. 1-68, March 1947.

Edmondson, C. H.
Behavior of coral planulae under altered saline and thermal conditions: Bernice P. Bishop Museum, Occasional Papers, vol. 18, no. 19, pp. 283-304, 1946.

Nugent, L. E., Jr.
Coral reefs in the Gilbert, Marshall, and Caroline Islands: Geol. Soc. America Bull., vol. 57, pp. 735-780, August 1946.

Shideler, W. H.
Beatricidae: Geol. Soc. America Bull., vol. 57, no. 12, pt. 2, p. 1230, 1946 (abstract).

Umbgrove, J. H. F.
Corals from a lower Pliocene patch reef in central Java: Jour. Paleontology, vol. 20, no. 6, pp. 521-542, 1946.

ECHINODERMS

Clark, Hubert Lyman
The Echinoderm fauna of Australia, its composition and its origin: Carnegie Inst. Washington Pub. 566, pp. 1-567, 1946.

Ekman, Sven, Zur
Verbreitungsgeschichte der warmwasserechinodermen im Stillen Ocean (Asteroidea, Ophiuroidea, Echinoidea): Nova Acta Regiae Societates Scientiarum Upsoliensis, ser. 4, vol. 14, no. 2, pp. 1-42, 1946.

BRYOZOA

Borg, Folke

Zur Kenntnis der Ökologie und des Lebenszyklus von Elektra crustulenta (Bryozoa Chilostomata) nebts Bemerkungen über den sog. braunen Körper bei den Bryozoen: Zool. Bidrag Uppsala, vol. 25, pp. 344-377, 5 figs., 1947.

This is the only chilostome found in the brackish waters of the Baltic, occurring as far north as 60°. It characteristically lives on Fucus, but in absence of that plant because of low salinities, is found on various substances, especially stones in the littoral region. Light is a comparatively unimportant factor in location of the colonies, but wave action and ice are major factors. (J. W. Hedgpeth).

MOLLUSKS

Hubendick, Bengst

Phylogenie und Tiergeographie der Siphonariinae, Zur Kenntnis der Phylogenie in der Ordnung Basommatophora und des Ursprungs der Pulmonatengruppe: Zool. Bidrag Uppsala, vol. 24, pp. 1-216, 107 figs., 1947.

A study of the comparative morphology of the genital apparatus, shell, kidneys, mantle opening, intestinal coils and nervous system of the Siphonariidae, together with discussion of ecological, distributional and paleontological data. Consideration of ecological requirements of siphonariids indicates that they cannot have spread actively over large area, and dispersion by larvae is improbable. Dispersion on seaweed is possible. The absence of assymetrical shells in northern Hemisphere fossils suggests an antarctic origin for the group, with the subgenus Siphonaria str. as a second northern branch. (J. W. Hedgpeth).

Kaneko, Sueo

Marine molluscan fauna from the Tashufang District, Kaohsiunghsein: Bull. Oceanographical Institute of Taiwan, no. 2, pp. 33-51, 1946.

Norton, Oswald A.

Some ecological observations on Dosinia discus Reeve at Beaufort, N. C.: Ecology, vol. 28, no. 2, pp. 199-204, 1947.

Richards, Horace G.

Pleistocene fossils in Eocene rock from New Jersey: Science, vol. 104, p. 354, 1946.

Test, Avery Ransome (Grant)

Speciation in limpets of the genus Acmaea: Contrib. Lab. of Vert. Biol. Univ. of Mich., no. 31, pp. 1-24, 1946.

Vokes, Harold E.

Contributions to Paleontology of the Lebanon Mts., Republic of Lebanon, Pt. 3, Pelecypod fauna of the "Olive Locality" (Aptian) at Abeih: Am. Mus. Natural History Bull., vol. 87, art. 3, pp. 141-215, 1946.

ARTHROPODS

Carpenter, Frank M.
Lower Permian insects from Oklahoma, Pt. 1, Intro. and the orders Megasecoptera, Protodonata, and Odonata: Am. Acad. Arts & Sci. Proc., vol. 76, no. 2, pp. 25-54, 1947.

Crane, Jocelyn
Eastern Pacific expeditions of the New York Zoological Society. XXXVIII. Intertidal Brachygnathous Crabs from the West Coast of Tropical America with special reference to Ecology: Zoologica (N. Y. Zoological Society), vol. 32, pt. 2, pp. 69-95, 1947.

Habitats of 79 species of intertidal brachygnathous crabs are treated and 9 distinct zones recognized. Two of these represent the association of particular species with the coral, Pocillopora, and with mangroves. (Paul L. Illg).

Milne, Lorus J.
(and Milne, Margery J.). Notes on the behavior of the ghost crab: Am. Naturalist, vol. 80, pp. 362-380, 1946.

Triebel, Erich
Zur Morphologie und Ökologie der fossilen Ostracoden: Senckenbergiana, Band 23, No. 4/6, pp. 294-400, 15 plates and 2 text-figs., 1941.

Williams, Louis G.
A comparative size study of the mole crab, Emerita talpoida Say, associated with epizoic Enteromorpha flexuosa (Wulfen) J. Ag: Ecology, vol. 28, no. 2, pp. 204-207, 1947.

VERTEBRATES

David, Lore
Significance of fish remains in Recent deposits off coast of southern California: Am. Assoc. Petroleum Geologist Bull., vol. 31, no. 2, pp. 367-370, 1947.

Maxson, John H.
Significance of the vertebrate fauna of Kucuk, Cekmece, Turkey: Geol. Soc. America Bull., vol. 57, no. 12, pt. 2, p. 1261, 1946 (abstract).

White, E. I.
The genus Phialaspis and the "Psammosteus limestones,": Quart. Jour. Geol. Soc. London, vol. 101, parts 3 and 4, nos. 403-4, pp. 207-242, 1946.

PROBLEMATICAL FOSSILS

Howell, B. F.
Silurian monocraterion Clintonense burrows showing the aperture: Wagner Free Inst. Sci. Bull., vol. 21, no. 4, pp. 29-40, 1946.

Young, Robert B.
Nodular Bodies in the Dolomite series: Trans. Geol. Soc. South Africa, vol. 48, (for 1945), pp. 43-48, 1946.

COMPLETED UNITS OF ANNOTATED BIBLIOGRAPHY OF MARINE ECOLOGY

BIBLIOGRAPHY ON THE ECOLOGY OF THE FORAMINIFERA

by

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The tests of Foraminifera are a useful and at times a tricky guide to paleoecological conditions: useful because of their relative abundance, state of preservation, ease of recovery, and numbers of species both in Recent and ancient marine sediments; tricky because of the frequency with which assemblages from different facies or even horizons become mixed due to erosion, and transportation by currents. However, controls are usually available since the reworking of a sediment results in sorting which eliminates certain growth stages of the species present, and there are usually additional guides in the form of skeletal remains of other groups.

The abundance of living Foraminifera in favorable regions varies from a few to many hundreds of individuals per square foot of bottom (51, 47, 56). *

Methods used in collecting living Foraminifera depend upon the depth of the water and the use that is to be made of them. Large numbers may be obtained from weed or eel grass, while in deeper water a special type of dredge is required, and when population counts are to be made, a special sampling device is necessary, (57,51). One should keep in mind that Foraminifera live on surfaces, never below them.

Assemblages of species represented by the tests observed in samples of sediments may be distinguished from the actual population living at the surface of the sediments through the use of a dredge that removes only surface materials. When samples taken in this manner are washed in a piece of bolting cloth one often finds that the residue contains a high percentage of living Foraminifera that can be readily distinguished from empty tests, (51, 48).

Life cycles are of interest because they explain the occurrence of two or more types of individuals within a species. The life cycle of Patellina (41) and Spirillina (43) include both a sexual and an asexual phase, and the cytological evidence in support of this work is in complete agreement with modern concepts. Other life cycles in which the cytological evidence is less complete include those of Tretomphalus (54) and several species of Discorbis (46). Similar life cycles in which evidence of a continuity of substance between the several stages are lacking or contraversal include Elphidium (34, 48, 29, 8), Peneroplis (68) Planorbulina (6, 8) Rotalia (25, 26) and Discorbis (26). Test trimorphism, due to the occurrence of two or more asexually produced generations

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* Numbers refer to papers in the Bibliography.

between succeeding sexual generations, has been proposed in many groups (26, 23, 43, 30) but the only evidence in support of this idea is in the fact that two or more asexual generations may follow in sequence in Sorites and related groups (34). Only one type of test has been recognized in a number of species and it would seem that these like certain species of Discorbis, Miliolina, and Bolivina are able to perpetuate themselves indefinitely without the intervention of a sexual phase (42).

Flagellated gametes or zoospores have been described in many genera (34, 8, 46, 53), and there is no doubt of their existence, but there is not a single instance in which cytological evidence presented in support of their presumed relationship to the parent, or progeny, or both, is complete and there is disagreement as to the nature of the gametes within the same species (54, 34, 8). Therefore one should presume that these so-called gametes are saprophites which had entered the tests of dead Foraminifera unless definite evidence to the contrary has been presented (46).

Mitotic division of nuclei was first conclusively demonstrated (41) and later substantiated (8) in Patellina. Later they were described and figured in other genera, but several of these should be re-investigated since there seems to be a most remarkable similarity in the figures in several papers by as many authors, except for the number of chromosomes represented, see Myers on Patellina (41), Føyn on Myxotheca (16) and Calvez on Iridia (8). The chromidial theory was used by early workers to explain the confused picture obtained from cytological preparations of Foraminifera, and to account for the increase in the numbers of nuclei immediately prior to reproduction (34, 65, 68). Later an attempt was made to bring this theory into line with the theory of the gene, but the idea is no longer acceptable to most cytologists (18).

The life span of active individuals in cultures range from a few days to many weeks (41, 43, 46, 54), while from statistical studies of populations in the sea it seems evident that some species live for from one to several years (48).

The time required to complete a life cycle varies with the length of the life span of the several types of individuals involved and may be from a few weeks to two years or more depending upon the species (48).

The number of progeny produced during asexual reproduction is usually proportional to the size of the test, and in sexual reproduction to the conditions under which the gametes are released and the rate of survival of the juveniles (41, 43, 46, 48, 54, 56).

Distribution of species over vast areas, especially those occurring at great depths, must have required a considerable period of time since there is no true pelagic stage in the life cycle of most Foraminifera. One means of dissemination is suggested by the fact that the tests of species known to live only on weed have been found in sediments several thousand miles from the nearest possible source and in several thousand meters of water, and were probably carried there on floating objects. It is also possible for juveniles or even adult individuals of a smaller species to be carried considerable distances by currents, and it is possible that currents at relatively great depths have a higher velocity than is usually acknowledged (53, 43, 33).

Ecological conditions in the sea that limit the geographic distribution of species have been inadequately studied. In its broader aspect the influence of temperature upon distribution is apparent without the use of a thermometer and the influence of salinity without making tests for total chlorides. In a like manner it is possible to determine those species that depend upon weed or grass for a substratum or those that live either on a soft or a firm mud bottom. This knowledge is useful, but there are other factors and combinations of factors that have equal or greater value. Samples of sediments may contain tests of a hundred or more species, but this number of species probably did not live in the area at any one time.

Temperature has been suggested as the dominant factor influencing the vertical distribution of species, but in the Java Sea, where the temperature does not vary by more than half a degree between the surface and the bottom at from 30 to 50 meters, there is as much or more evidence of distinct life zones (55) as there is off the coast of California at depths in excess of 2,000 meters and a difference in temperature between the surface and the bottom of some 15° C. This work of Natland's is a splendid example of the application of ecological data to stratigraphic geology, but its value could have been enhanced had he determined which species actually inhabited the several life zones. Unfortunately suitable equipment and methods were not developed until after this work was published. Norton also made an interesting contribution, but again he was dealing with empty tests, some of which may have been derived from other zones (34). The same criticism hold for the work of Le Roy and others.

Only one attempt has thus far been made to determine the effect of measurable ecological conditions in the sea upon the life activities of a foraminifer, and in this instance it was found that growth and reproduction was for the most part limited to a period when the temperature and salinity were near the lowest for the year and when food organisms were most abundant (48, 53). It has been suggested that a decrease in salinity causes a reduction in the size and thickness of the tests (25) and that low temperatures result in a reduction in the size of pelagic species (Rhumbler). These pelagic species do not survive for long in shallow seas (55, 47), neither are they numerous in certain parts of the oceans as in the coastal waters of the Pacific Coast of North America.

Living Foraminifera are interesting organisms. The streaming pseudopodia are fascinating to watch (60) and it is especially interesting to observe feeding and reproductive activities through the microscope, but the rate of activity is amazingly slow. It is also interesting to observe growth through the addition of new chambers to a test and to contemplate that most Protozoa would produce a new generation more frequently than a foraminifer adds a new chamber to its test. In other words, most Protozoa would produce astronomical numbers of progeny in the time required for Elphidium to produce a test having from 30 to 50 chambers (41, 43, 54).

Food organisms utilized by many species of Foraminifera are easily determined from the cytoplasmic inclusions observed in thin sections. In many species the apertures of the tests are too small to admit organisms appreciably larger than bacteria, and in these digestion takes place outside of the test. In the abyssal depths of the ocean it is probable that bacteria and products of bacterial decomposition are the principle source of food (59, 47, 53, 29).

The color of living Foraminifera occurring on coral reefs made them things of beauty, while those taken in the intertidal zone in temperate regions show only a limited range of color, and when taken in deeper water the color would be monotonous were it not for the color of the mineral substances of which the tests are composed (47, 55, 50).

Cytological studies of nuclear division have been discussed. When these preparations are stained to show fatty bodies, it becomes evident that the oil-like globules observed in a crushed preparation of a living organism is actually lipoid in nature (8). Mitochondria have also been described (14), but as yet no thorough study of cytoplasmic inclusions has been made except in the case of the nuclei.

Zooxanthellae, the so-called green cells that are responsible for much of the color in corals and sea anemones, are also abundant in certain Foraminifera, but there is reason to believe that these plant cells which are regarded as symbionts are little more than parasites in the Foraminifera (53, 52, 56, 68).

Parasites in the Foraminifera are not uncommon, and are especially numerous during the dormant season. Calvez has described several, and Myers found Nematode worms a frequent parasite in certain species (9, 53).

Natural enemies include many Annelids, Holothurians, Sea Stars, and even Arthropods, or in fact, most organisms that burrow in or feed upon the organic content of marine sediments. A study of the content of the intestines of some of these enemies make it obvious that they actually select rather than accidentally engulf the Foraminifera (50).

Cultures of many species of Foraminifera are easily maintained in the laboratory, but few attempts have been made to rear more than a single generation of any but the smallest species. Work in this field should be attempted, but not without giving due consideration to the time required to complete the life cycle of the species selected (53, 44).

The following is a working bibliography and can be readily completed from the publications listed. Lister's 1895 paper is a classic. His report in E. Ray Lancaster's "Treatise on Zoology" is basic. Brady's work in the report of the Challenger Expedition is invaluable, and more recent developments on the biology of the Foraminifera are described in papers by Calvez, Jepps, and Myers.

The work of Natland perhaps more than that of any other investigator suggests values to be derived through the use of Recent Foraminifera, and a knowledge of the conditions under which they live, as guides to the conditions that existed in previous horizons.

(Bibliographic references follow.)

General References

Brady, H. — Report on the Foraminifera dredged by H.M.S. CHALLENGER during the years 1873-1876: Challenger Repts., Zoology, vol. IX, 1884.

Cushman, J. A. — Foraminifera, their classification and economic use. Harvard Univ. Press, 1940.

Galloway, J. J. — A manual of Foraminifera (James Furman Kemp memorial series, Pub. 1). 483 pp., 42 pls. Bloomington, Ind., Principia Press, 1933.

Glaesner, M. F. — Principles of micropaleontology. John Wiley & Sons, 1947.

Le Roy, L. W. — A preliminary study of the microfaunal facies along a traverse across Peper Bay, west coast of Java: De ingenieur in Nederlandsch-Indie IV, no. 8, pp. 130-133, 1938.

Natland, M. L. — The temperature and depth distribution of some recent and fossil Foraminifera in the Southern California region: California Univ. Scripps Inst. Oceanography Tech. ser. Bull., vol. 3, no. 10, pp. 225-230, 1933.

Norton, R. D. — Ecologic relations of some Foraminifera: California Univ. Scripps Inst. Oceanography Tech. ser. Bull., vol. 2, no. 9, pp. 351-388, 3 figs., 6 tables, 1930.

Rhumbler, L. — Die Foraminiferen (Thalamoporen) der Plankton Pt. 1; Ergeb. Plankton-Exped. Humboldt Stiftung, Band 3, pp. 1-331, pls. 1-39, 1911.

Vaughan, T. W. — Ecology of modern marine organisms with reference to paleogeography: Geol. Soc. America Bull., vol. 51, pp. 433-468, 1940.

Significant papers on the biology of the Foraminifera

1. Calkins, G. N. — The biology of the Protozoa. Lea and Feiberger, Philadelphia, 1933.

2. Calvez, J. le — Embryons a cinq loges de Planorbulina mediterraneansis (d'Orbigny) et trimorphisme de cette species: Zool. Soc. France Bull., vol. 59, pp. 284-290, 1934.

3. _____ — Les gametès de quelques Foraminifères: Acad. Sci. Paris Comptes rendus, vol. 204, pp. 1505-1507, text figs. 1-3, 1935.

4. _____ — Observations sur le Genre Iridia: Archiv Zool. Experimental Gén., vol. 79, pp. 115-131, pl. 1, text figs. I-VII, 1936.

5. Calvez, J. le — Modification du test des Foraminifêres pelagiques avec le reproduction Orbulina universa d'Orbigny, et Tretomphalus bulloides d'Orbigny: Annales Protist., Paris, 5, pp. 125-133, figs. 1-8, 1936.

6. _____ — Processus schizogimiques chez le Foraminifêre Planorbulina mediterraneansis d'Orbigny: Acad. Sci. Paris Comptes rendus, vol. 204, pp. 147-149, figs. 1-4, 1937.

7. _____ — Les Chromosomes spireaux de le premiêre mitotse schizogomique du Foraminifêre Patellina corrugata Will: Acad. Sci. Paris Comptes rendus, vol. 205, pp. 1106-1108, 6 figs., 1937.

8. _____ — Recherches sur les Foraminifêres. Protistologica - LXXXVI: Archiv Zool. Experimentale Gén., Tome 80, pp. 163-333, pls. IIa, VII, 1938.

9. _____ — Trophosphaera planorbulina n. gen. n.sp. protists Parasite des Foraminifêres Planorbulina mediterraneansis. Protistologica LXXXII: Archiv Zool. Experimentale Gén., Tome 80, pp. 425-443, 1939.

10. _____ — Recherches sur les Foraminifêres. 1. Development et reproduction: Archiv Zool. Experimentale Gén., Tome 80, pp. 163-333, pls. 2-7, 28 figs., 1939.

11. Chapman, F. — Notes on the appearance of some Foraminifera in the living condition, from the Challenger Collection: Royal Soc. Edinburgh. Proc., 1899-1901, pp. 391-395, pls. 1-3.

12. Cushman, J. A. — Observations on living specimens of Iridia diaphana, a species of Foraminifera: U.S. Nat. Mus. Proc., vol. 57, pp. 153-158, pls. 19-21, 1920.

13. _____ — The interrelation of Foraminifera and Algae: Washington Acad. Sci. Jour., vol. 20, pp. 395-396, 1930.

14. Doyle, Wm. L. — Distribution of mitochondria in the Foraminiferan Iridia diaphana: Science, vol. 81, no. 2103, 1935.

15. Earland, A. — On Cymballopora bulloides d'Orbigny and its internal structure: Queckett Micr. Club Jour., vol. 8, p. 309, pl. 16, figs. 6-9, 1902.

16. Föyn, Björn — Foraminifer studies. Der Lebenzyklus von Discorbina vilardaboana d'Orbigny: Bergene Mus. Arbok., 2, 1936.

17. _____ — Über die Kernverhaltnisse der Foraminifere Myxotheca arneliga Schaudinn: Archiv für Protisten, Band 87, Heft 2, 1936.

18. Hartman, M. Polynergide Kerne. Studien Über multiple Kernteilung und generative Chromidien bei Protozoa: Biol. Centralbl., Band XXIX, pp. 481-487, 491-506, 1909.

19. Heron-Allen, A. Contribution to the study of Bionomics and reproductive processes in the Foraminifera. Extracted from Sir John Murray Laboratory Notebooks on H.M.S. CHALLENGER: Phil. Trans., vol. 206, pp. 227-279, pls. 13-18, 1915.

20. _____ The further and final studies of J. J. Lister upon the reproductive processes of Polystomella crispa L.: Smithsonian Misc. Coll., vol. LXXXII, pp. 1-11, 1930.

21. Hofker, J. On heterogomy in Foraminifera: Tijds. Ned. Dierkund. Ver. (2) 19, pp. 68-70, 1925.

22. _____ Notizen über Foraminiferen die Golfes von Neapel: Napoli Stat. Zool. Publ., 10, pp. 385-406, 1930.

23. _____ Preliminary note on a static statement of Trimorphism in Biloculina sarsi Schlumberger: Tijds. Ned. Dierkund. Ver., (3) 2, pp. 179-184, 1931.

24. _____ Die Fortpflanzung der Foraminiferen: Annales Protist. Paris, 3, pp. 25-34, 1930.

25. _____ Die Generationswechsel von Rotalia beccari var. flevensis n.var: Zellforsch. Mikr. Anat., 19, pp. 756-758, 1 pl., 1930.

26. _____ Foraminifera of the Siboga Expedition. Part II: Monograph IV, Siboga Exped., pp. 79-170, 1930.

27. Jensen, P. Über Individuelle Physiologische Unterscheide zwischen Zelle der Gleichen Art: Archiv für Physiologie Pfluger, 62, 1895.

28. Jepps, M. W. Contribution to the study of Gromia oviformis Dujardin: Quart. Jour. Micr. Sci., vol. 70, pt. IV, 1926.

29. _____ Studies on Polystomella Lamark (Foraminifera): United Kingdom Marine Biol. Assoc. Jour., 25, pp. 607-666, pls. 4-5, figs. 1-9, 1942.

30. Keijzer, J. On variability in East Indian Foraminifera: Reprint of Temminckia, vol. 1, 1936.

31. Kemma, A. Sur le caractere naturel de la division des Foraminifêres en imperfores et perfores: Belgique Royal Soc. Malacol. Ann., 37, Bull. LXXII, 2 figs.

32. Kofoid, C. A. An interpretation of conflicting views as to the life cycle of the Foraminifera: Science, vol. 79, no. 2054, p. 436, 1934.

33. Le Bour, M. V. The microplankton to Plymouth Sound from the region beyond the breakwater: Assoc. Marine Biol. Jour., vol. XI, 1916-18.

34. Lister, J. J. Contributions to the life history of the Foraminifera: Royal Phil. Soc. Trans., B., vol. 186, pp. 401-454, pls. 6-9, 1895.

35. _____ The Foraminifera in Lancaster, E.R., A treatise on Zoology, I, pt. 1, fasc. 2, London, 1903.

36. Lowman, S. W. Ecologic relationships of some brackish-water and shallow water marine Foraminifera of Louisiana: Report of the Committee on Sedimentation, Division of Geology and Geography, National Research Council, Washington, March, 1942.

37. Moebius, E. Foraminifera of the Island of Mauritius, in Beitrage Meeresfauna Insel Mauritus, p. 98, 1880.

38. Murray, SirJohn On the distribution of the pelagic Foraminifera at the surface and on the floor of the ocean: Nat. Sci. 1897, pp. 17-27.

39. Myers, E. H. Multiple tests in the Foraminifera: Nat. Acad. Sci. Proc., vol. 19, no. 10, pp. 893-899, 1933.

40. _____ The life history of Patellina corrugata, a Foraminifer, Science, vol. 79, no. 2054, pp. 435-437, 1934.

41. _____ The life history of Patellina corrugata Williamson, a Foraminifer: California Univ. Scripps Inst. Oceanography Tech. ser. Bull., vol. 3, no. 15, 1935.

42. _____ Morphogenesis of the test and the biological significance of dimorphism in the Foraminifer Patellina corrugata Williamson: California Univ. Scripps Inst. Oceanography Tech. ser. Bull. vol. 3, no. 16, 1935.

43. _____ The life cycle of Sprillina vivipara Ehrenberg with some notes on morphogenesis, systematics and distribution in the Foraminifera: Royal Micr. Soc. Jour., vol. LVI, 1936.

44. _____ Culture methods for marine Foraminifera of the littoral zone, in: Galtsoff, Paul, et al, Culture methods for invertebrate animals. Comstock Publishing Co., Ithaca, 1937.

45. _____ The present state of our knowledge concerning the life cycle of the Foraminifera: Nat. Acad. Sci. Proc., vol. 24, no. 1, 1938.

46. Myers, E. H. Observations on the origin and fate of flagellated gametes in multiple tests of Discorbis (Foraminifera): United Kingdom Marine Biol. Assoc. Jour., vol XXIV, 1940.

47. _____ Ecological studies of the Foraminifera: Report of the Subcommittee on the Ecology of Marine Organisms, Division of Geology and Geography, National Research Council, Ann. Rept., Appendix A-1, 1941.

48. _____ A quantitative study of the productivity of the Foraminifera in the sea: Am. Phil. Soc. Proc., vol. 85, no. 41, 1942.

49. _____ Biological evidence as to the rate at which tests of the Foraminifera are contributed to the marine sediments: Jour. Paleontology, vol. 16, no. 3, pp. 397-398, 1942.

50. _____ Biology of the Foraminifera and their significance in Paleoecology: New York Acad. Sci. Trans., ser. II, vol. L, no. 6, 1942.

51. _____ Rate at which Foraminifera are contributed to marine sediments: Jour. Sedimentary Petrology, vol. 12, no. 2, pp. 92-95, fig. 1, 1942.

52. _____ Ecologic relationships of some Recent and fossil Foraminifera: Report of the Committee on Marine Ecology as related to Paleontology, Division of Geology and Geography, National Research Council, Ann. Rept., Appendix N, 1942.

53. _____ Life activities of the Foraminifera in relation to marine ecology: Am. Phil. Soc. Proc., vol. 85, no. 3, 1943.

54. _____ Biology, ecology and morphogenesis of a pelagic Foraminifer: Stanford Univ. Publ., Univ. ser. Biol. Sci., 1943.

55. _____ Recent studies of sediments in the Java Sea and their significance in relation to stratigraphic and petroleum geology: Science and Scientists of the Netherlands East Indies, Surinam and Curacao. New York City, 1945.

56. _____ Ecologic relationships of larger Foraminifera: Report of the Committee on Marine Ecology as related to Paleontology, Division of Geology and Geography, National Research Council, Ann. Rept., Appendix Q, 1943.

57. _____ Collecting Recent Foraminifera: Report of the Committee on Marine Ecology as related to Paleontology, Division of Geology and Geography, National Research Council, Ann. Rept., Appendix H, 1945.

58. _____ The Foraminifera. Encyclopedia Brittanica, 4000 words. (In press). 1947?

59. Sandon, H. The food of the Protozoa. Publication of the Faculty of Science, The Egyptian University, no. 1, Cairo, 1932.

60. _____ Pseudopodial movements in the Foraminifera: Nature, vol. 133, p. 761, 1934.

61. Schaudinn, F. Die Fortpflanzing der Foraminiferen und eine neue Art der Kernvermehrung: Biol. Zentralblatt, 14, pp. 161-166, 1894.

62. _____ Ueber den Dimorphismus der Foraminiferen: Gesell. naturf. Freunde Berlin Sitzungsber., Band 10, pp. 87-97, 1895.

63. _____ Ueber Plastogamie der Foraminiferen: Gesell. naturf. Freunde Berlin Sitzungsber., Band 10, pp. 179-180, 1895.

64. _____ Untersuchungen an Foraminiferen. I. Calcituba polymorpha: S. Wiss. Zool., 59, pp. 192-232, 1895.

65. _____ Untersuchungen über die Fortpflanzing einiger Rhizopoden. Polystomella crispa: Arb. a. d. Kais. Gesundheitsamte, Band 19, Heft 3, pp. 547-576, 1903.

66. Soaces, Jose Manso Piras Une Nouvelle methods pour l'etude biologique et paleontologique des Foraminifères: Portugosa Soc. Nat. Sci. Bull., 11 (19), 1933.

67. Sparck, A. On the importance of quantitative investigations of the bottom fauna in marine biology: J. Conseil Copenhagen, 10, pp. 3-19, Foraminifera, 1935.

68. Winter, F. W. Zur kenntniss der Thalmaporen. I. Untersuchungen über Peneroplis pertusus: Archiv Protist., 10, pp. 1-114, 1907.

ANNOTATED BIBLIOGRAPHY OF BRACHIOPOD ECOLOGY

by

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Up to the present time very little has been written on the ecology of brachiopods. Most work on modern brachiopods deals with their anatomy, embryology, and morphology. Except in a general way, not much has been said about how they live or their relationships to each other and to contemporary associates on the sea floor. With the publication of the embryology of Terebratella inconspicua by Percival, interest in modern brachiopod biology is reviving. The work of Hatai and Nomura on the modern and Tertiary brachiopods is an excellent beginning in ecology in a region where many living brachiopods are available in local waters. The numerous brachiopods of Japanese, Australian, New Zealand, and South African areas offer great possibilities for ecological studies. No detailed account of these animals in terms of modern views on ecology has ever been made, but such a study is needed.

The annotated listing here presented should be considered preliminary.

Allan, R. S.
On a neglected factor in brachiopod migration: Rec. Canterbury Mus., vol. IV, no. 3, pp. 157-165, 1937.

A possible but unproved means of brachiopod distribution is suggested, by means of attachment of brachiopods to the shells of migratory pectens.

Incidentally, mention is made of the occurrence of the large terebratulid Neothyris lenticularis (Desh.) lying loose on the sea bottom as the result of atrophy of the pedicle.

Ashworth, J. H.
On larvae of Lingula and Pelagodiscus (Discinisca): Trans. Roy. Soc. Edinburgh, vol. 51, pp. 45-69, 1918.

Describes larvae of Lingula collected in the Red Sea and Indian Ocean. One larva of Lingula is of particular interest because it was taken in water of 2200 fathoms depth, 200 miles from the nearest coast (Ceylon). Lingula is generally found between tide marks or in shallow water.

Six free-swimming larvae of Pelagodiscus were taken in water 40 fathoms deep west of Cape Comorin in the Indian Ocean. The adult generally occupies deep water; it is recorded from 200 to 2425 fathoms, but is generally found in depths greater than 1000 fathoms. The conditions off Cape Comorin suggest that the source of the larvae occurs in shallow water.

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Broderip, W. J.
Descriptions of some new species of Cuvier's family of Brachiopoda: Proc. Zool. Soc., pp. 141-144, 1835.

Contains habitat data on several recent species. Discinisca lamellosa was found on a sandy bottom at a depth of 5 to 9 fathoms, "the individuals being in many instances piled in layers one over the other." They were also found attached to a wrecked ship, giving the appearance of flat fungi. Discinisca cumingii was found "attached to the lower sides of stones in sandy mud at low water, and in some instances at a depth of six fathoms."

Dall, W. H.
Report on the Brachiopoda obtained by the United States Coast Survey Expedition in charge of L. F. de Pourtales, with a revision of the Craniidae and Discinidae: Harvard Mus. Com. Zoology Bull., vol. 3, no. 1, p. 11, 1871.

Contains mostly anatomical and taxonomic data relating to Carribean brachiopods. Dall mentions an interesting case of Terebratulina cailleti (Crosse) which had been covered by a sponge. The pedicle was exceedingly long, the animal apparently having lengthened the pedicle as the sponge grew toward it. Although the original attachment of the pedicle to the rock remained, a second attachment had taken place nearer the shell by a bunch of rootlets from the underside.

Dall, W. H.
Annotated list of the recent Brachiopoda in the collection of the United States National Museum, with descriptions of thirty-three new forms: U. S. Nat. Mus. Proc., vol. 57, pp. 261-377, 1920.

Replete with data on distribution and depth.

Davidson, T.
What is a brachiopod? Geol. Mag., Decade II, vol. IV, nos. 4-6, pp. 1-31 1877.

A general discussion of brachiopods, their morphology, distribution and classification.

Davidson, T.
Report on the Brachiopoda dredged by H. M. S. Challenger during the years 1873-1876: Rept. Sci. Results voyage of H. M. S. Challenger 1873-1876. Zoology, vol. 1, pt. 1. Rept. on the Brachiopoda, 1880.

Contains bathymetric, bottom and distribution data on some 34 species dredged on the 68,890 miles of the Challenger voyage.

Davidson, T.
A monograph of recent Brachiopoda: Trans. Linnean Soc. London, 2d ser. Zoology, vol. IV, pts. 1-3, 1886-8.

A summary of all that was known at the time of Recent Brachiopoda. Many data on bathymetric range, bottom and habits where known.

DuBois, H. M.
Variation induced in brachiopods by environmental conditions: Puget Sound Marine Sta. Publ., vol. 1, no. 16, pp. 177-183, 1916.

Collections of the brachiopod Terebratalia obsoleta (Sowerby) taken from 30-50 fathoms in various environments including quiet waters to strong wave and current action varied from wide spirifer-like shells to round and almost smooth forms. The shorter and more gibbous shells were shown through detailed measurements, to be developed where the water is roughest. Abnormalities of the shell were thought to be produced by bruising of the tender mantle-edge by waves and currents.

Fenton, C. L.
A parasitic brachiopod: Nautilus, vol. 46, pp. 52-54, 1932.

Terebratalia transversa caurina (Gould) was found living inside the shell of a large gastropod, Argobuccinum oregonense (Redfield). The brachiopod larva had entered a rent in the mantle of the gastropod and had attained a considerable size in this unusual environment.

Fischer, P. and D. P. Oehlert. Brachiopodes Expeditions scientific du Travailleur et du Talisman pendant les annees 1880-1883, pp. 1-140, 1891.

Contains bathymetric and distributional data on 16 species of brachiopods from the Lusitanian province.

Hall, J.
(assisted by J. M. Clarke). An introduction to the study of the Brachiopoda intended as a handbook for the use of students. New York State Geol. Rept. for 1891, pp. 7-93, 1894.

Contains an excellent summary of knowledge of brachiopods, fossil and recent up to the time of its appearance. Pages 7-18 contain a summary of habits of life, and also embody a map of the world showing distribution of the know modern species and their bathymetric range. A discussion of morphology and biology follows. The remarks on variations in form and ornamentation are fairly extended.

Hatai, K. M.
Cenozoic Brachiopoda from Japan: Sci. Repts. Tohoku Imp. Univ., 2d ser. (Geology), vol. XX, pp. 6-122, 1940.

Contains a summary of all previous knowledge of the Japanese Recent and Tertiary brachiopods. Bathymetric and bottom data are given for all modern species, and character of sediments and associated fossils for Tertiary species. Inferences are drawn as to depth of water for fossil forms based on knowledge of occurrence of Recent types.

Helmcke, J. G.
Brachiopoda, in Kukenthal and Krumback, Handbuch der Zoologie: Bd. 3, Hälfte 2, Lief, 13, pp. 209-211, Berlin 1939.

A detailed and extensive discussion of modern brachiopods; contains a brief account of brachiopod ecology on page 209-211.

Brachiopods live only in the sea and are found at all depths down to 5000 meters. Most brachiopods are attached by a pedicle or by one valve but the Lingula-series could move. They burrow in the sand of warm shelf-seas, and live in vertical burrows with the setaceous front margin protruding, through which water enters on each side and is expelled at the middle. Other brachiopods can only adjust themselves on the pedicle and open the valves to draw in water.

The only possibility for distribution occurs in the larval stage. Most larvae swim about freely. In Argyrotheca the free-swimming stage lasts only a few hours but in Terebratulina about 2 weeks. In contrast to the latter larvae in which the alimentary canal is incapable of functioning, are the larvae of Lingula which possess a gut which opens through the mouth and anus and even develops mid-gut glands. It would thus be expected that the animal could nourish itself and would be widely distributed because of its long-larval existence. However that contradicts all observations. All brachiopods occur living with one another in great numbers, and the young animals grow up between the older ones. This occurs especially clearly with species of Discinisca; Every older shell is crowded with young animals of all sizes. Some species practise brooding in different degrees. Discinisca protects the larvae between the shells. Liothyrella antarctica Blochmann is the only known brachiopod of Recent species to hold the eggs between the spiral arms. In Argyrotheca the brooding is further pronounced: the eggs are attached in the enlarged excretory organs which serve as brood pouches. In Lacazella mediterranea Risso the anterior body wall of the female is inverted to form a broodpouch in which the two oldest tentacles hand. The larvae attach themselves on the tentacles until they have reached a certain size, then loosen themselves and swim about freely like the larvae of Argyrotheca, before they finally attach themselves.

Individual species appear to be little influenced by such factors as temperature and salinity. Some brachiopods flourish for long periods of time in aquaria and other unfavorable environments.

Enemies of the Brachiopoda are not known. Blochmann found in the intestine of only one Crania anomala Müller "a Monozystidee in noticeable number" and Shipley saw in the mantle cavity of Argyrotheca cordata Risso a small and unknown parasitic copepod.

Hertlein, L. G. and U. S. Grant IV.
The Cenozoic Brachiopoda of western North America: California Univ. at Los Angeles Publ. in Math. & Phys. Sci., vol. 3, 1944.

Contains numerous data as to depth, temperature, and habitat which may be applied to an understanding of the fossil species related to the Recent forms discussed.

Lamont, A.
Brachiopod morphology in relation to environment: "Cement, Lime and Gravel," May, 1934 (reprint pages unnumbered).

Contemporaneous inhabitants of contrasting sedimentary facies are considered. A correlation between type of sediment, morphology and ornamentation was

observed. Muddy bottom forms, because of low oxygen content of waters near muddy bottoms, tend to have compressed form with maximum oxygen-intake surface. Muddy bottom forms also tend to be fine-lined. Sandy bottom forms have strong ribs, large body space, and unextended lateral margins. Limestone forms are sometimes smooth-shelled, sometimes coarse-ribbed.

Morse, E. S.

Observations on living brachiopods: Boston Soc. Nat. Hist. Mem., vol. 5, no. 8, pp. 313-386, 1902. Review by C. Schuchert, Am. Geol., vol. 31, pp. 112-121, 1903.

Embodies the observations of many years on Recent brachiopods of the east coast of the United States and of Japan. Emphasis is made on the great vitality of the inarticulate brachiopods such as Lingula and Glottidia. Their long geological history may be attributed to their great vitality and the fact that they have inhabited the littoral region during all this time.

The power of movement by use of the peduncle and setae of the body is described for Glottidia. The formation of the Sand-burrow and the process of burrowing into the sand is described. Similar habits of Lingula lepidula Adams are also described. The method of feeding by protruding the front end above the surface of the sand, and the formation of incurrent and excurrent canals through the development of three tubes by the anterior setae is explained. After discussion of the habits of these creatures the anatomy and physiology of observed brachiopods are discussed.

Nomura, S. and K. Hatai.

A note concerning data on the bathymetric range of certain marine animals and remarks on the geology of the Neogene formations in northeast Honsyû, Japan and their depth of sedimentation as indicated by the fossil fauna: Saito Ho-on Kai Museum Research Bull., no. 9, no. 10, pp. 245-248, 273-286, 287, 1936.

Depth data for many living brachiopods as well as those occurring in Japanese waters are listed. It is pointed out that Lingula is unknown in waters deeper than 23 fathoms. Like molluscs, brachiopods become smaller in size with increasing depth. The shallow water forms are larger than deep water ones, have heavier or thicker shells, and some are brilliantly colored. Most brachiopods prefer a clean (not muddy) bottom of rather coarse texture, but they are also found on bottoms of fine material. The information derived from these data together with that taken from other types of animals is applied to a study of the Neogene strata.

Orton, J. H.

On ciliary mechanisms in brachiopods and some Polychaetes, with a comparison of the ciliary mechanisms on the gills of molluscs. Protocordata, Brachiopods, and Cryptocephalous, Polychaetes, and an account of the endostyle of Crepidula and its allies: Jour. Marine Biol. Assoc. U. K. (n. s.), vol. 10, pp. 283-311, 1914.

Advances the theory that development of a fold and sulcus, or what amounts to trilobation of the shell, may have been required to facilitate the passage of incurrent and excurrent streams of water used in the aeration of the mantle and for food gathering.

Percival, E.

A contribution to the life-history of the brachiopod, Terebratella inconspicua Sowerby: Trans. Roy. Soc. New Zealand, vol. 74, pt. 1, pp. 1-23, 1944.

In connection with his studies of Terebratella inconspicua Sowerby, Percival furnishes some notes on the ecology of the species. The animals were found on the breastwork of a disused jetty at Governors Bay, and on the inner face of the retaining wall of the Gladstone Wharf of the Inner Harbour, at Lyttelton. The animals are abundant at the latter place, and in both localities the brachiopods occur up to about half tide mark. They are attached to stones and other solid objects, but are hidden in places where the water is gentle in its movements.

The breeding season is from early April to late May. The sexes occur in a ratio of about 1:1. Early life of the embryo is spent in the mantle-cavity of the female. Very small larvae swim near the substratum but in late free life they tended to congregate toward the light, but after 20-30 hours of freedom "there was a movement toward the substratum." After attachment many young may become weeded out by overcrowding. Growth in Lyttelton Harbour is slow and the life of the population is short, about 4 years. About 2/3 of the population is of the first year class, $\frac{1}{4}$ of the second year, 1/7 of the third year and 1/34 of the fourth year.

Schuchert, C.

Paleogeographic and geologic significance of Recent Brachiopoda: Geol. Soc. America Bull., vol. 22, pp. 258-275, 1911.

The modern brachiopod fauna consists of 158 established species in 33 genera. Of these species, 29 belong to Inarticulata genera and the remainder to the Articulata. About 80 percent of the brachiopods inhabit water shallower than 1000 feet and over 70 percent live in water over 600 feet in depth. Brachiopods generally indicate shallow water of continental or epicontinental seas.

Lingula and Discinisca of the Inarticulata are warm, shallow water species and scarcely any species are common to two zoogeographical provinces. They are thus excellent shore-line indicators.

Of the 129 articulates 65 percent live in water from tide zone down to 100 fathoms. A few only occupy water deeper than 100 fathoms. Abyssal species are thin-shelled, more or less transparent, and generally small.

Twenty-three living genera have fossil representatives; 2 lived since Ordovician times; 6 since the Jurassic; 4 since Cretaceous; 1 since Miocene; 7 since Pliocene and 3 since Pleistocene. The truly abyssal forms are of stocks probably older than Mesozoic. No Paleozoic brachiopod is known to have become abyssal, although Lingula still lives in its old shore zone habitat. The oceans probably did not become exceedingly deep until early Mesozoic time, and deepening has gone on since then. Only 16 percent of living brachiopod species are known as fossils and none is older than Eocene.

The 33 known genera are readily grouped into 5 great areas: the deep sea realm, the Boreal region, the Austral region, Oceanica, and Gondwana.

Thomson, J. A.
Australasian Antarctic Expedition 1911-14: Brachiopoda. Ser. C,-Zoology and Botany, vol. IV, pt. 3, 1918.

Part I describes 16 species of Antarctic brachiopods and furnishes bathmetri and bottom data. Part II is concerned with the geographical distribution of the brachiopods in the southern seas. Because of the limited power of distribution of their larvae, brachiopods cannot cross oceans from coast to coast. Consequently cases of discontinuous distribution in shallow water have a great geological significance. Thomson discusses the brachiopod fauna of the abyss and shows that it is composed of 3 species confined to the Pacific, and 2 species widely distributed in both hemispheres. These facts indicate that the deeps are impassable barriers to the more numerous shallow water dwellers. The southern realm is divided into 19 geographical districts, ten of which have yielded brachiopods. The Australian district has produced the largest number of brachiopods, but others producing a considerable number are: New Zealand, South Africa, South America, Antarctic, Keruguelen, St. Paul Island, Macquarrie Islands, and Marion Island districts. Few species of shallow water forms are common to Northern and Southern seas, and 5 species so identified need reexamination. Only one other species is common to two of the southern geographical districts; all other southern species are confined to single geographical districts. Discontinuous distribution, as described in European and American coasts of the North Atlantic, is not found in southern seas.

Relationships of the modern brachiopod faunas to the Tertiary are discussed together with some of the geological implications.

Thomson, J. A.
Brachiopod Morphology and Genera (Recent and Tertiary). New Zealand Board of Science and Art, Mar. 7, 1927.

This is a source book for information relating to morphology, taxonomy, and stratigraphy of Recent and Tertiary genera. Ecological data occur in the discussions of many of the genera.

COMPLETED UNITS OF ANNOTATED BIBLIOGRAPHY OF PALEOECOLOGY

ANNOTATED BIBLIOGRAPHY OF BRACHIOPOD PALEOECOLOGY

by

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Absence of a good discussion on modern brachiopod ecology is a great handicap to an understanding of fossil brachiopods. This understanding is the more remote when one considers that the ecology of fossil brachiopods is interpreted in terms of modern ones. Furthermore, many types of brachiopods, abundant in the past, are unrepresented by living forms. Nothing like the strophomenids, the richthofenids, leptodids, paterinids are extant. In fact the only Protremate group living is the family Thecidiidae, which includes two very aberrant forms, but they do give an idea as to how the cemented articulate brachiopods lived. Thus the ecology of the great body of fossil brachiopods must be learned by applying all information relating to sediments, paleogeography, morphology, and any other information that can be gleaned from stratigraphy.

The present offering is admittedly not complete; it is the first effort made in a limited time. Many choice morsels of paleoecology relating to brachiopods are still to be found among the specific descriptions and remarks on species. To search all of these kernels among the vast mass of brachiopod literature will require many years. It is hoped however that before the appearance of the Treatise on Paleoecology that the brachiopod section will be materially expanded.

Allan, R. S.
New records of the genus Lingula (Brachiopoda) from Tertiary strata in New Zealand: Trans. Roy. Soc. New Zealand, vol. 65, pp. 383-385, 1936.

Under the heading "Lingula as a Paleic Indicator", and on the basis of Clements' statement that "The significance of paleic indicators rests upon the conviction that ecological processes were essentially the same during the geological past as they are today", Allan points out the significance of Lingula in an ancient deposit. This brachiopod is said to be an indicator of tropical and warm temperate seas and to indicate a shallow water environment. Lingula is thus a warm climate indicator because it is today confined to warm waters and it is an environment indicator because it is known to inhabit shallow waters only (0-10 fms. according to Allan).

Clarke, J. M.
The Oriskany fauna of Becraft Mountain, Columbia County, New York: New York State Mus. Mem., no. 3, vol. 3, pp. 78-79, 1900.

Under a heading called "The original Oriskany sandstone" Clarke describes the distribution of the sandy facies, its broken occurrence, variable

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thickness, lack of lime, and restricted faunal content. "Such discontinuity of the sand deposits of the Oriskany are indications of an exposed and broken coast line, in the western part of the state, the sand feebly encroaching on areas of entirely different deposition." The author states further that the large brachiopods Spirifer arenosus, Rensselaeria ovoides, Hipparionyx proximus and Meristella lata, which are generally found in the sand lenses, could not have lived on such a bottom and in a "sea whose depth favored such deposition." They are species of the calcareous facies of the Oriskany swept out of their deeper and more calcareous facies into the sands.

Clarke, J. M.
The beginnings of dependent life: New York State Mus. Bull., 121, pp. 146-169, 1908.

Contains some incidental references to brachiopods in relation to certain dependent organisms. Mention is made of the constant use of the brachiopod Chonetes sarcinulatus Schloth. as a base of attachment for the coral Pleurodictyum problematicum Goldfuss in the German Lower Devonian. This coral species invariably is attached to Chonetes, but the similar P. styloporum (Eaton) of the New York Hamilton is just as invariable in its habit of attaching to a snail, generally a species of Loxonema.

Mention is made of the sponges Clionolithes and Caulostrepsis and the fact that several species attack brachiopod shells.

The legend to plate 52 bears a description of certain Devonian brachiopods showing holes bored into their shells by predatory gastropods.

Cooper, G. A.
Brachiopod Ecology and Paleoecology, Rept. Committee on Paleoecology, pp. 26-53, 1936-1937.

A few remarks on brachiopod anatomy are followed by a discussion of brachiopods is past and present faunas. The distribution of modern brachiopods is discussed, about 1/3 the brachiopods occupy deep waters; slightly more than 1/3 occupy the deeps; the remainder occur from tide zone to the deeps. Habitats of recent brachiopods, their numbers, and geological history are also considered. Methods in paleoecology include analogy with modern animals, position of the fossils in the rock, associated fossils, the enclosing sediments, and paleogeography.

Brachiopod adaptations such as folding, lobation, plication, cementation, alation and mucronation, elongation, compressed form, resupination, reversion, spinescence and geniculation are all helpful to the brachiopod in making it possible to keep the front margin out of the mud. The form and size of the pedicle are discussed and attention given to the pedicle of Chlidonophora which is long and slender with a frayed end that attaches the shell to the bottom as do the roots of a plant. The possibility that many of the mud-dwelling Paleozoic brachiopods were provided with this type of pedicle is discussed. Brachiopod enemies and brachiopod embryology in relation to distribution are discussed. The larvae of the few inarticulates known have a longer free-swimming stage than those of the known articulates. Brachiopod color, pathology, commensalism and parasitism are considered.

Cooper, G. A.
Ecology of some Permian brachiopods: Rept. Committee on Marine Ecology as related to Paleontology, Nat. Research Council, Div. Geol. & Geog., Appendix N, pp. 36-37, 1942.

Life habits of Permian productids based on silicified material dissolved out of limestone are described. Aulosteges has attachment spines; Productus leonardensis King is attached when young but lives unattached on the sea-bottom when adult; Productus? pileolus Shumard is anchored by long spines; Avonia lives unattached but can function in various attitudes because its long spines keep its margin from the bottom; Richthofenia is anchored by spines while Leptodus is ostreiform in habit. Scacchinella forms masses of individuals cemented to each other.

Davidson, T.
Palaeontological notes on the brackiopoda. No. 2. On the families Stropomenidae and Productidae: The Geologist, March, pp. 112-114, 1859.

The mode of existence of all Productidae appears not to have been the same in all cases. Productus giganteus for example, must have lived with the ventral valve down on the sea-bottom because that valve is massive and heavy. If this species lived with the dorsal valve down, its muscles would not have been strong enough to have lifted the heavy opposite valve.

Fenton, C. L. and M. A. Fenton.
Some snail borings of Paleozoic age: Am. Midland Naturalist, vol. 12, no. 12, pp. 522-528, 1931.

In the Paleozoic, brachiopods generally outnumbered the pelecypods, and were thus the chief prey of snails. The borings are of two types: One with beveled edges, definitely gastropod in origin; the other without beveled edges. The two types occur in shells of the Richmond (Ordovician). Gastropods are too numerous in the Richmond to be certain which genus was responsible for the borings. In the Hamilton of New York and Michigan, bored shells occur with the snails Diaphorostoma and Platyceras. The latter more commonly attaches itself to the tegmen of crinoids, but Diaphorostoma may have been a borer. The occurrence of the two types of snails in the Devonian may have a connection with the two types of borings. In the Richmond four genera have been found bored: Sowerbyella, Rafinesquina, Dalmanella, and Platystrophia. In the Devonian seven genera are bored: Atrypa, Meristella, Parazyga, "Spirifer," Leptostrophia, Rhipidomella, and Stropheodonta.

Fenton, C. L. and M. A. Fenton.
Orientation and injury in the genus Atrypa: Am. Midland Naturalist, vol. 13, no. 2, pp. 63-74, 1932.

Young Atrypa was a normal telotremate brachiopod, but in the adult form the brachial valve became greatly enlarged and the pedicle too small to hold the shell in place, especially in ephebic and gerontic growth. In late life the pedicle became non-functional and the animal came to rest on its pedicle valve with its dorsally folded anterior margin well above the mud of the bottom.

Distorted shells are produced during the period when fixed by the pedicle, the animal then grows against a fixed object or is crowded. Injuries in which the shell is broken and later repaired may have resulted from the falling over of "horn" corals on the sessile brachiopod.

Grabau, A. W.

Geology and Paleontology of Eighteenmile Creek and the lake-shore sections of Erie County, New York: Buffalo Soc. Nat. Hist., Bull. 6, pp. 319-365, 1899.

Chapter III, entitled "The relation of marine bionomy and stratigraphy" discusses the principles of marine bionomy, bionomic districts and the bionomic characteristics of marine organisms. A brief discussion of Brachiopoda appears on p. 350. This discussion is repeated in Principles of Stratigraphy, New York 1924, p. 1014.

Lamont, A.

Lower Paleozoic brachiopoda of the Girvan District: suggestions on morphology in relation to environment: Anns. & Mag. Nat. Hist., ser. 10, vol. 14, p. 161-184, 1934.

This is an attempt to interpret brachiopod morphology and adaptation to the type of bottom in which the creatures dwelt. In the Balcletchie mudstones, compressed, concavo-convex, finely ornamented types of shell predominate. The pedicle of these types is often atrophied and the shells lie loosely on the muddy floor. Concentric rugae and extensions of the cardinal angles are thought to be adaptations in warding off silt from the opening shell on a muddy bottom. Rugae on the lower valve help the shell to maintain stability on the sea-floor. Fine ornament appears to be an adaptation to a muddy environment. In overlying coarse sandstone and pebbly conglomerate at Balcletchie, a different assemblage of strong ribbed and plicate types appears, although a few of the mud-dwelling types survive.

In the Whitehouse Group at Shalloch Mill and Whitehouse Bridge, strong ribbed and finely ribbed forms occur together in an association thought to be unnatural. It appears probable that the shells may have been swept together from different environments.

In the Drummock Group, Schizophorella is an abundant brachiopod. It is a trilobed form thought to have been so attached that currents wheeled the shell about causing the pedicle end to face the current. It probably rested with the dorsal valve on the mud. The trilobation created lateral incurrent canals and a median excurrent canal for nourishing streams of water.

Direct evidence of life attitude is not often to be had but it is thought, following an argument of Davidson, that the animal rested on the heavier valve, which in many instances is the ventral valve but may be the dorsal. In the Mulloch Hill group, the smooth biconvex Whitfieldella is nearly always found resting on the dorsal valve. In the Saugh Hill Group, it is observed that extended cardinal margin and narrow body space are common in a muddy environment. This means that the organism collected food and oxygen from a greater water area. H. B. Moore has shown that mud is an oxygen absorber and therefore the water immediately in contact with mud would be poor in oxygen.

The evidence from Girvan shows that strong ribbing is commonest in shells that lived in sand; fine ribbing is characteristic of the mud-dwellers. Ribbing is a means to increased rigidity but is also an aid to maintaining stability on the sea-floor. This theory is consistent with that of Morse, indicating that external ribbing corresponds to internal furrowing, and is induced and guided by setae given off along the mantle margin. Such setae serve to exclude foreign material. Therefore they tend to be closer together in mud-dwellers, and give rise to closer spaced radii.

Muir-Wood, H. M.

The British Carboniferous Producti. II.-Productus (sensu stricto); Semireticulatus and Longispinus Groups. Mem. Geol. Surv. Great Britian, Paleont., vol. III, pt. I, pp. 24-30, 1928.

The author disagrees with the generally accepted view of orientation of productid valves during life, i.e. resting on the ventral valve, and contends that they lived with the ventral valve uppermost and the margin buried in the mud. It is also suggested that currents of water may have passed into the shell via the hollow spines. This may have taken place in conjunction with punctae.

Noetling, F.

Untersuchungen über die Familie Lyttoniidae Waag. emend. Noetling. Palaeontographica, pp. 129-153, 1905.

Noetling visualizes the Permian genus Oldhamina, a member of the Lyttoniidae having a strongly convex ventral valve, as having been fixed by the posterior of the ventral valve to solid objects on the substratum when young. In the adult stage it rested unattached on the sea-bottom with the dorsal valve downward, partly buried in mud in quiet water at a depth not less than 100 meters. The fact that at least half of the animals were found with both valves together indicates quiet water. Lyttonia, with a gently convex ventral valve, on the other hand, is found with an accumulation of crinoid debris, and is thought to have lain unattached on the sea-bottom in moving water and with the dorsal valve down.

Ruedemann, R.

Paleozoic plankton of North America: Geol. Soc. America Mem. 2, pp. 33-34; 41; 56-61, 1934.

Under a discussion of Paleozoic plankton in general, Ruedemann states that "Brachiopods found in association with the graptolites in the normal graptolite shales are small primitive Inarticulata, with more or less chitinous valves that undoubtedly were attached to the floating seaweeds. They belong to the genera Paterula, Leptobolus, Acrotreta, Schizotreta, Lingula, Lingulella, Orbiculoidea, and Eunoa.

Eunoa, a member of the Trematidae according to Clarke, one of the largest inarticulate brachiopods known, occurs in the Deep Kill shale. Inasmuch as no benthonic fauna is known, it is inferred that Eunoa lives as epiplankton on floating seaweeds.

The small size of the brachiopds, their thin chitinous valves, primitive structure, generic longevity, and wide distribution point unmistakably to a pelagic habitat in the open ocean "where wide distribution and slow development were assured under prevailing stable conditions. No brachiopods are found in the gulf-weed fauna of today."

Conodonts associated with Lingula and plant remains together with the black shale, suggest foul bottoms of the sea.

Black shales of the Devonian include a few brachiopods with thin shells which may have lived among and upon gulf weeds, owing their small size and thin shell to this fact rather than to life on a foul bottom. Pteropods may have been swept in to the Devonian sea from the Atlantic. Lack of clearly planktonic elements other than conodonts, indicates lack of incursions of planktonic life from the open ocean in Chattanooga shale and later Paleozoic black shale areas.

Sardeson, F. W.
Pioneer repopulation of devastated sea-bottoms: Pan-Am. Geologist, vol. 46, pp. 273-288, 1926.

Describes the effects of a fall of volcanic ash (now bentonite) into the Ordovician sea (Platteville) of Minnesota and the obliteration of much of the brachiopod fauna occuping the area affected. Of the brachiopods those regarded as bottom dwellers, such as Orthis tricenaria Conrad were obliterated. Early repopulation was by brachiopods interpreted as living attached to sea-weeds. Bottom dwellers did not return to the area until later.

Sardeson, F. W.
Ordovicic brachiopod habit: Pan-Am. Geologist, vol. 51, pp. 23-40, 1929.

Circumstantial evidence as to the habit of life of certain Middle Ordovician brachiopods is described. Three species, Dinorthis /Campylorthis/ deflecta Conrad, Orthis /Hesperorthis/ tricenaria Conrad, and Rafinesquina /Opikina/ minnesotensis (Winchell), were found in their position of growth. Each occurred with the beak down and interarea essentially horizontal to the basal bedding plane of the layer in which they occurred. In each case the larger, convex valve lies obliquely over the smaller, plane or concave valve. In the case of Dinorthis the dorsal (brachial) valve is the larger, but in the other two the ventral (pedicle) valve is the larger. The animals were apparently entombed while still alive because they are filled with crystalline calcite, not sediment.

With these specimens occuring in position of growth occur many other shells such as Strophomena incurvata (Shepard), Pianodema (sic) subaequata Conrad, and Rhynchotrema minnesotensis (Sardeson). These specimens lie prone in the sediments. It is inferred, because none of them occur in growth position that they must have been attached to seaweeds, and fell helter-skelter on the bottom at death.

Schmidt, H.
Zur Morphogenie der Rhynchonelliden: Senckenbergiana, Bd. 19, pp. 22-60, 1937.

Discusses the shell morphology and growth of some Devonian rhynchonellids from Germany and France. Of ecological interest is the elaboration and explanation of the lobation at the front of the shell. This takes place in two ways: one by the prominent folding of one valve (brachial); the other by the development of a tongue that fits into a deep reentrant in the opposite (brachial) valve. Both types tend to divide the anterior into three channels when the valves are agape. The lateral two are for incurrent streams, and the middle one for out-going currents carrying body waste. Some of the shells are provided with points or spines at the ends of grooves between the costae of the ornament. These spines protrude obliquely into the valves and serve as sieves to keep out large particles. The shells, such as some species of Uncinulus, which have long needle-like projections may have had the spines surrounded by the mantle which bore cilia. These mantle projections may have helped to direct currents into the body cavity.

Shimer, H. V.

Dwarf faunas: Am. Naturalist, vol. 42, no. 499, pp. 472-490, 1908.

The chief agencies in dwarfing faunas are: 1) a change in the chemical content of the water due to a) freshening, b) concentration of salt or iron or other chemicals, c) increase in H_2S and other gases. 2) Presence of mud and mechanical impurities; 3) floating habitat; 4) variations in temperature; and 5) extremes in depth of water.

Examples of dwarf faunas involving brachiopods are those of the Cobleskill, Rondout, Manlius and Bertie and the cause is probably greater density of the water and in part presence of lime mud. The fauna of the Tully pyrite and of the Clinton iron ore are dwarfed by presence of iron.7/

The Devonian black shales (Genesee) are accumulations at great depth in water having imperfect vertical circulation. An accessory agent is suggested, i.e., that the black shale is a Sargasso sea deposit. A Carboniferous fauna in the limestones at Windsor, Nova Scotia was dwarfed because of variation in depth and content of the water, and the influence of the formation of gypsum.

The Permian fauna of central Europe is said to be dwarfed because of association with red beds, and increasing saltiness of the water.

Dwarfing shows itself in acquirement of old age characters; retention of youthful characters because growth is very slow in an unfavorable environment.

Stamp, L. D.

Some practical aspects of correlation - a criticism: Prof. Geol. Assoc., vol. XXXVI, part 1, p. 11, 1925.

The factors controlling the distribution of marine organisms are: depth; temperature; salinity and gases; clarity of the water; food supply and the

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7/ Mineralogists tell me that the Tully pyrite may be limestone lenses replaced by pyrite. This would cast doubt on the theories advanced for this instance of dwarfing. G. A. C.

nature of the sea-bottom. The range of brachiopods is discussed and mention made that, although the larvae are free-swimming, they cannot be widely distributed because of the short time during which they are mobile. This is in conflict with the belief that some brachiopods "have been spread evenly over vast areas at the time (hemera) of which they are characteristic." The supposition that these sluggish creatures were characteristic of such a short space of time as a hemera, and during that time were enormously widespread, introduces many difficulties that are not easily explained. Where these brachiopods are not found, it is supposed that the deposits of that hemera have been removed. The brachiopods migrate so slowly that they may appear with fossils of a later date. "Instead of recognizing the result of slow migration, repeated destruction and redeposition of beds are invoked to explain such phenomena."

Teichert, C.

Biostratigraphie der Poramboniten. Neuen Jahrb. für Mineral., Geol. & Paleont., BB. 63, Abt. B, pp. 209-210, 1930.

Porambonites is often found in life position upright in the sediments with the heavy beaks down and the anterior margin up. This position is further indicated by the fact that specimens are often found with the beak end filled with mud, while the remaining part of the interior has the walls lined with calcite crystals deposited in the empty interior.

Lingula was also found vertical to the bedding in the position in which it lived during life.

Trechmann, C. T.

Some remarkably preserved brachiopods from the lower magnesian limstone of Durham: Geol. Mag., vol. LVIII, no. 12, pp. 538-543, 1921.

Unusual specimens of the Permian Productus /Horridonia/ horridus Sowerby having hinge spines on the ventral valve nearly 3 inches in length, and with the hinge region of the dorsal valve provided with long spines, are described. To the long spines of one specimen, Epithyris /Dielasma/ elongata Schloth. and a species of Strophalosia are attached.

Wanner, J. and H. Sieverts.

Zur Kenntnis der permischen Brachiopoden von Timor. 1. Lyttoniidae und ihre biologische und stammesgeschichtliche Bedeutung: Neuen Jahrb. für Mineral., Geol.,Paleont., BB. 74, Abt. B, pp. 257-265, 1935.

The prevalent opinion of the mode of life of Lyttonia (preoccupied by Leptodus), is that the animal was attached by its ventral beak end when young but that it broke from the attachment and lived free on the sea-bottom. Lyttonia catenata Wanner and Sieverts, attached itself by the beak end to the stem of crinoids, but lived with the plane of the valves parallel to the stem. This symbiotic arrangement had the advantage to the brachiopod of getting it off the bottom, protecting it from bottom marauders, and putting it in position to share in the food-gathering currents or water created by movement of the crinoid arms. Some Lyttoniidae such as Cardinocrania, Paralyttonia and Poikilosakos were attached by the entire surface of the ventral valve throughout life.

The life habits of Oldhamina according to Noetling's views are discussed and the conclusion reached that the shells of this genus may have lived free on the sea-bottom in the adult stage.

Noetling and others claimed that weak musculature and muscle attachments indicated that the dorsal valve could not be opened, and that its lateral slits served like a sieve to let in water. The lateral branches of the dorsal valve join the lateral septa of the ventral valve and close the shells to the exterior. The valves must have been able to open, according to the authors. The dorsal valve increases its food-gathering ability by the splitting of the dorsal valve into many side branches which has essentially the same function as the brachidium.

Yakovlev, N. N.

The phenomena of the parasitism, commensalism and symbiosis in the Palaeozoic Invertebrata: Annuaire Soc. Paleontologique Russie, tom. 4, pp. 113-124, 1926.

A symbiotic relationship between the coral Aulopora and brachiopods is described in which the coral derives benefit in feeding by the water currents produced by the brachiopod, and the coral, by virtue of its stinging ability, protects the brachiopod.

ANNOTATED BIBLIOGRAPHY OF PALEOECOLOGY OF CALIFORNIA TERTIARY MARINE MOLLUSKS

by

Wendell P. Woodring
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This bibliography could be greatly expanded, as many publications on California Tertiary marine mollusks contain brief statements bearing on paleoecology, chiefly on the temperature facies. A few publications containing only brief statements are included in the bibliography, either because of their historical interest or because the statements are fairly specific. If any publications that include more than brief generalized conclusions are omitted, that omission is inadvertent.

Arnold, Ralph

1. The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, Calif.: California Acad. Sci. Mem., vol. 3, 420 pp., 37 pls., 1903. (Reprint Leland Stanford Jr. Univ., Contr. Biol. Hopki Seaside Lab., Nov. 31, 1903.) (See pp. 14-33.)

   Discussion of temperature facies of Pleistocene faunas of San Pedro distri Though brief, it has had profound influence.

2. Environment of the Tertiary faunas of the Pacific coast of United States: Jour. Geology, vol. 17, pp. 509-533, 5 figs., 1909.

   Mostly paleogeography and generalized temperature facies.

Bailey, T. L.

Lateral change of fauna in the lower Pleistocene: Geol. Soc. America Bull., vol. 46, pp. 489-502, pl. 44, 1 fig., 1935.

Mollusks in mudstone and sandstone of varying stratigraphic position in Pleistocene of Ventura district show close correlation with type of sediments, both being controlled by depth.

Carpenter, P. P.

On the Pleistocene fossils collected by Col. E. Jewett at Santa Barbara, Calif., with descriptions of new species: Ann. Mag. Nat. History, 3d ser., vol. 17, pp. 274-278, 1866.

An early discussion of presence of northern species in a California Pleistocene fauna, a subject to which California paleontologists have devoted much attention. It is pointed out that a fauna includes southern species, a subject that has plagued California paleontologists.

Crickmay, C. H.

The anomalous stratigraphy of Deadman's Island, Calif.: Jour. Geology, vol. 37, pp. 617-638, 1929.

Fauna of part of Pleistocene deposits assigned to Santa Barbara formation indicates depth of 50 to 100 fathoms.

Dickerson, R. E.
Tertiary and Quaternary history of the Petaluma, Point Reyes, and Santa Rosa quadrangles: California Acad. Sci. Proc., 4th ser., vol. 11, no. 19, pp. 527-601, pls. 17-41, 1922. (See pp. 565-570.)

Fauna of Pleistocene Millerton formation indicates climate considerably warmer than at present time, suggesting interglacial period.

Eaton, J. E.
(and Grant, U. S., and Allen, H. B.). Miocene of Caliente Range and environs, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 25, pp. 193-262, 9 pls., 14 figs., 1941.

Includes discussion of ecologic features, principally effect of basinward and strandward location on faunal facies.

Grant, U. S., IV
(and Gale, H. R.). Catalogue of the marine Pliocene and Pleistocene Mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, 1,036, pp., 32 pls., 15 figs., 1931.

Part I (by Gale) includes discussion of temperature facies of late Pliocene and Pleistocene faunas of selected districts in coastal California and San Joaquin Valley, and discussion of conversion of temperature facies into glacial-interglacial chronology.

Louderback, G. D.
The Monterey series in California: California Univ. Dept. Geol. Bull., vol. 7, pp. 177-241, 1913. (See pp. 204-206.)

Close correlation of depth facies and faunal facies has for the most part been ignored.

Merriam, J. C.
A note on the fauna of the lower Miocene in California: California Univ. Dept. Geol. Bull., vol. 3, pp. 377-381, 1904. (See p. 377.)

Brief, but clear, statement of correlation of depth facies and faunal facies.

Oldroyd, T. S.
The fossils of the lower San Pedro fauna at the Nob Hill cut, San Pedro, Calif.: U. S. Nat. Mus. Proc., vol. 65, art. 22, 39 pp., 2 pls., 1924.

These Pleistocene mollusks lived in an estuary or on a flat, which was ordinarily protected, but was exposed to unusually severe storms.

Schenck, H. G.
1. (and Keen, A. M.). An index-method for comparing molluscan faunules: Am. Philos. Soc. Proc., vol. 77, pp. 161-182, 4 figs., 1937.

Method for computing index-latitude by determination of median of midpoints of latitude range of species and its application to Pliocene and Pleistocene faunas.

2. Geological application of biometrical analysis of molluscan assemblages: Jour. Paleontology, vol. 19, pp. 504-521, pls. 66, 67, 3 figs., 1945.

Additional examples of method described by Schenck and Keen, 1937.

Smith, J. P.
Climatic relations of the Tertiary and Quaternary faunas of the California region: California Acad. Sci. Proc. 4th ser., vol. 9, pp. 123-173, pl. 9, 1919.

Temperature zoning of pacific coast Tertiary and Pleistocene marine faunas.

Stewart, Ralph
Geology of Reef Ridge, Coalinga district, Calif.: U. S. Geol. Survey Prof. Paper 205, pp. 81-115, pls. 9-17, figs. 10-13, 1946.

Faunal associations in Eocene Avenal sandstone suggest deeper and quieter water southward. Part of Eocene Kreyenhagen shale may have been deposited at depths as great as 1,000 fathoms. Two faunal zones in Miocene Temblor sandstone represent different facies, the lower evidently deposited in deeper water and more open sea. Possibility that fauna of San Ramon formation represents Temblor-like facies of Vaqueros age suggested.

Vokes, H. E.
Paleoecology of the fauna of the Domengine formation; middle Eocene, Calif.: Sixth Pacific Sci. Cong., 1939, Proc., vol. 2, pp. 597-605, 3 figs., 1940.

Discussion of probable Temperature, depth, and salinity.

Willett, George
1. Report on Pleistocene molluscan fauna at Capistrano Beach, Orange County, Calif.: Southern California Acad. Sci. Bull., vol. 36, pt. 3, pp. 105-107, 1937.

The fossils indicate shallow water, probably less than 5 fathoms, and temperature of water was lower than at present time.

2. An upper Pleistocene fauna from the Baldwin Hills, Los Angeles County, Calif.: San Diego Soc. Nat. History Trans., vol. 8, no. 30, pp. 379 406, pls. 25, 26, 1937.

The fossils are inferred to have lived on sandy bottom, at depth of 10 to 12 fathoms, near mouth of bay or slough.

Woodring, W. P.
1. Lower Pleiocene mollusks and echinoids from the Los Angeles Basin, Calif., and their inferred environment: U. S. Geol. Survey Prof. Paper 190, 67 pp., 9 pls., 2 figs., 1938.

Most widely distributed mollusks in lower Pliocene Repetto formation are of deep-water facies, suggesting depths of 300 to 600 fathoms. This conclusion essentially agrees with Natland's earlier analysis, based on the much more abundant Foraminifera.

2. (and Stewart, Ralph, and Richards, R. W.). Geology of the Kettleman Hills oil field, Calif.; stratigraphy, paleontology, and structure: U. S. Geol. Survey Prof. Paper 195, 170 pp., 57 pls., 15 figs., 1940 [1941]. (See pp. 99-102.)

Pliocene faunas lived in shallow waters of inland sea. Estuaries were filled with brackish or fresh water. Climatic interpretation of faunas advocated by some paleontologists considered doubtful.

3. (and Bramlette, M. N. and Kew, W. S. W.). Geology and paleontology of Palos Verdes Hills, Calif.: U. S. Geol. Survey Prof. Paper 207, 145 pp., 37 pls., 16 figs., 1946. (See pp. 86-96, 100-103.)

Moderate-depth facies (10 to 100 fathoms) of mollusks from early Pleistocene Lomita marl and Timms Point silt is emphasized. Varying depth facies and other complications are to be considered in attempts to interpret temperature facies in terms of climate.

ANNOTATED BIBLIOGRAPHY OF PALEOECOLOGY OF PALEOZOIC OSTRACODES

by

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The ecology of Paleozoic ostracodes has been dealt with by relatively few paleontologists, and the majority of these workers, as is only logical, have inferred much about the probable ecological factors governing Paleozoic forms from the environment of ostracodes living today. Kummerow (1939, 1940), and Scott and Summerson (1946) appear to have made the most intensive and objective studies of the probable life habits and living realm of these minute crustaceans of Paleozoic time.

Ostracodes have been found in a great varity of sediments of Paleozoic age. Although more abundant in the calcareous shales, particularly immediately above or below limestones, Paleozoic ostracodes have been reported and described from argillaceous limestone, "pure" limestone, siliceous limestone, chert, dolomitic limestone, bituminous limestone, arenaceous limestone, sandstone, argillaceous sandstone, arenaceous shale, and clay shale. Paleozoic ostracodes have been described from calcareous lenses in diabases and tuffs, and red shales of fresh-water origin, but are reportedly not present in black, fissile shales. Siliceous rocks seem to be among the less suitable host rocks. However, silicified and cherty rocks contain ostracode tests, as these rocks are for the most part secondary; this is true also of the iron ores which contain ostracodes. Furthermore, ostracodes have been recorded from beds which were formed under conditions so unfavorable to other forms of invertebrate life as to cause the latter to be dwarfed (Loomis, 1903). The ease of extracting ostracodes from the rock for study accounts, in part, for their reported relative abundance in certain types of sediments, for example, calcareous shales. On the other hand, it is very difficult and sometimes impossible to extract calcareous shells from pure limestone. Furthermore, in dolomitic rocks the granular molds and casts of the original shells can be prepared for study only with difficulty. This is true also of silicified shells in a siliceous matrix.

The abundance of ostracodes in certain types of sediments may not mean that these particular rocks record the optimum environments, but rather that the environment became so unfavorable that the animals were unable to live and died in great numbers.

Furthermore, inasmuch as ostracode tests are of low specific gravity and small size, they were probably amenable to transportation, both by waves and by currents of air or water, to regions not at all conducive to ostracode life and growth.

Ostracodes occurred in the Paleozoic in rocks deposited under marine, brackish, and fresh water conditions. In many cases the marine species are said to be distinct from those fresh water species. (Armstrong, 1871; Merrett, 1924). Cooper (1946), and Monahan (1931) note contradictory evidence, however.

Paleozoic marine ostracodes are thought to represent mainly benthonic and planktonic life, although some nektonic representatives are reported (Kummerow, 1938, 1940). The ostracodes occur principally in sediments believed to represent neritic zone.

Ostracodes in the Paleozoic were associated with almost all types of invertebrates; in particular they occurred with brachiopods, gastropods, pelecypods, bryozoans, pteropods, trilobites, cephalpods, foraminifers, and, except in black shales, with conodonts.

This manuscript has benefited from the suggestions derived from the critical reading of Dr. Chalmer L. Cooper, Dr. Myra Keen, Dr. S. W. Muller, Mrs. Betty Kellett Nadeau, and Mr. I. G. Sohn.

The literature published both abroad and in the United States, including that of 1946, has been thoroughly combed, and several of the numbers of many 1947 publications have been perused for material dealing with Paleozoic ostracode ecology. Although the author has attempted to make the following bibliography complete, it is quite possible that there have been omissions. The ecologic parts of the references have been summarized, usually in the original author's words. The annotated ecologic references are as follows:

Armstrong, James

A general catalogue of the fossils and their mode of occurrence and an index to the principal localities, in On the Carboniferous fossils of the west of Scotland, by John Young: Geol. Soc. Glasgow, Trans., vol. 3, suppl., pp. 25-29, 1871. (See esp. p. 24.)

There are two groups--one marine, the other exclusively brackish or fresh water.

Bailey, Willard F.

Micropaleontology and stratigraphy of the Lower Pennsylvanian of central Missouri: Jour. Paleontology, vol. 9, pp. 489-490, 492-494, 1935.

Ostracodes are more abundant in the light colored, calcareous shales, except Healdia, which is abundant in the balck shales.

Bassler, R. S.

Stratigraphic significance of Ostracoda: Geol. Soc. America Bull., vol. 22, pp. 275-278, 1911.

Recent ostracodes in salt and fresh water are cosmopolitan and apparently unlimited bathymetrically--swimming at the surface or creeping over the bottom. After death the shells are scattered far and wide by the winds and water. Judging from their associates in the ancient continental seas, most of the Paleozoic representatives were much more limited in their habitat. Paleozoic ostracodes occur in all kinds of rocks. Though most abundant in calcareous sediments, they are also very common in highly siliceous strata, in all kinds of shales, and even in relatively coarse, beach-worn sandstone.

Boucek, Bedrich

Die Ostracoden des bohmischen Ludlows: Neues Jahrb., Beilage Band, Abt. B, pp. 31-98, pls. 2-6, 8 figs., 1936. (See esp. pp. 34-36, 85-86)

Ostracodes are found in limestone, in fine grained marl with trilobites and brachiopods, in flagstones, and in limestone concretions in shales. The abundance in concretions is surprising; the shells must have been dropped on the calm, clayey floor, and the calcium carbonate of the shell (plus that of other invertebrates) consolidated them in the concretions. In the flagstones the shells must have been deposited as a fine, organic sand in near-coastal waters, either in place, or drifted. Large ostracodes are rare and scattered because of the currents.

Their wide geographic distribution is related to fineness of the shells; for the living animal, or more often, empty shells are drifted by the waves and currents to distant regions.

The ostracodes are found only with certain petrographically characteristic horizons and layers, and are completely lacking in the other strata. These facts are due less to the short life span of the forms than to the life-conditions or to the transportation of empty shells.

Cooper, Chalmer L.

Occurrence and stratigraphic distribution of Paleozoic ostracodes: Jour. Paleontology, vol. 16, pp. 764-776, 1942 [also in Illinois State Geol. Survey, Rept. Invest. 83, 1942]. (See esp. pp. 767-776.)

In the Paleozoic, marine species greatly exceed the fresh-water ones, largely because of the paucity of continental sediments in the stratigraphic column until near the end of the era. In marine beds the ostracodes are most abundant in the calcareous shales adjacent to, and in the thin shale partings within, limestones. Though probably as abundant in some limestones as in the adjacent shales, they are much more difficult to extract for study. Sandstones or siliceous shales are the leanest sources.

Cooper, Chalmer L.

Pennsylvania ostracodes of Illinois: Illinois State Geol. Survey Bull. 70, 126 pp., 21 pls., 36 figs., 1946. (See esp. pp. 15, 17.)

The ostracodes occur mainly in calcareous shales above and below marine limestones. Fresh-water faunas are associated with Spirorbis and plant spores. The typical marine species which usually occur in the limestones and shales are generally absent above the coals, though typically marine forms sometimes do occur in these beds. However, many marine forms can exist in environments having considerable variation in the degree of salinity so that their presence does not necessarily indicate a marine deposit of normal salinity. On the other hand, as fresh-water forms are unable to exist in saline water, their presence indicates a fresh-water deposit, unless it can be shown that the fresh-water species were transported from their native habitat.

Coryell, H. N.
(and Rogatz, Henry). A study of the ostracode fauna of the Arroyo formation, Clearfork Group of the Permian in Tom Green County, Texas: Am. Midland Naturalist, vol. 13, pp. 378-391, pls. 34-35, 1932. (See esp. pp. 378-379.)

That this is a provincial fauna is shown by the great number of individuals, but relatively few genera and species. The isolation must have been complete and the time required fairly great to have produced the divergence of structure in species of the genus Knoxina from the simplest to the most complicated. This basin was being cut off from the sea, with the deposition of red muds and silts, a lessening of salinity.

Deeke, W.
Palaentologische Betrachtungen, VII, Über Crustaceen: Neues Jahrb., Bd. 1, pp. 112-126, 1915. (See esp. pp. 114-116.)

In order to produce sediments bearing the massive ostracode shells (Beyrichia, Primitia)—that part of the sea must have had calm water—strand or shallow water—perhaps with thick plant growth—algae, etc.

Gillette, Tracy
The Clinton of western and central New York: New York State Mus. Bull. 341, 188 pp., 20 figs., 4 tables, 1947. (See esp. pp. 17-24, table 4.)

Ostracodes occur in the Clinton in limestones, shales, sandstones, and iron ores, and thus seem to have been able to live and be preserved under a greater variety of conditions than any other class of organisms living in the Clinton seas.

Gutschick, Raymond D.
Niagaran ostracodes from Burlington, Wisconsin: Illinois State Acad. Sci., Trans., vol. 34, no. 2, pp. 164-165, 1941.

The fossil forms and the high content of argillaceous material suggest proximity to shoreline conditions of sedimentation.

Harlton, Bruce H.
Micropaleontology of the Pennsylvanian Johns Valley shale of the Ouachita Mountains, Oklahoma, and its relationship to the Mississippian Caney shale: Jour. Paleontology, vol. 7, pp. 3-29, 7 pls., 1933. (See esp. pp. 4-5)

A great number of distinct organisms flourished in the Johns Valley sea with its muddy deposits. In other correlative areas it is observed that most of them flourished as well in a sea forming calcareous deposits. (This is a general statement, not restricted to any group of organisms).

Hekker, R. F.
A Leperditia from the Middle Devonian of the Leningrad province: Bull. de l'Academie des Sciences de l'U.R.S.S., Serie Biologique, no. 2, pp. 232-240, 7 figs., 1939 (English summary).

Associated with a few fishes and trochiliscids. The sparse fauna and flora, as well as the dolomitic rocks, indicate that Leperditia geographica Hekker inhabited a basin with abnormal salinity, connected with the sea, and not a lake.

Holland, W. C.
Ostracodes of the Nineveh limestone of Pennsylvania and West Virginia: Carnegie Mus. Annals, vol. 22, pp. 343-350, pls. 25, 1934.

In a fresh-water limestone, associated with fish teeth and scales, Spirorbis, and a minute gastropod of the Pupiidae family.

Johnson, J. Harland
Calcareous algae of the upper Leadville limestone near Glenwood Springs, Colorado: Geol. Soc. America Bull., vol. 56, pp. 829-848, 5 pls., 1 fig., 1945. (See esp. p. 842.)

The limestone was deposited in the temperate, shallow to moderately shallow water with luxuriant algal growth.

Johnson, W. R.
The Ostracoda of the Missouri Series in Nebraska: Nebraska Geol. Survey, Paper 11, 52 pp., 5 pls., 1936.

In general, ostracodes were found to be most abundant in light colored, calcareous shales. Some shaly limestones were ostracode-bearing, but only a few were obtained from hard, relatively pure limestones. Some occurred in dark gray shales, but none in black fissile shales or in red or green shales. The ostracodes were associated with foraminifers, except fusulinids, and with conodonts, except in the highly carbonaceous shales.

Jones, T. Rupert
(Kirkby, James W., and Young, John). On Carbonia, its horizons and conditions of occurrence in Scotland, especially in Fife: Edinburgh Geol Soc., Trans. (1898), vol. 7, pp. 420-442, 1899.

Leperditia scotburdigalensis Jones and Kirkby is a dwarf variety of the marine L. okeni Munster and may have been modified by migration into brackish or estuarine water. Carbonia seems to have flourished most generally in waters not frequented by marine animals, yet sometimes they occur together; thus this genus was able to live in both marine and fresh water.

Kirkby, James W.
On the zones of marine fossils in the Calciferous sandstone series of Fife (Scotland): Geol. Soc. London, Quart. Jour., vol. 36, pp. 559-590, 1880.

The ostracodes occur in the thin limestones interbedded with bituminous shales. They may or may not indicate a marine origin of the beds.

Kummerow, E. H. Egmont

Die Ostrakoden und Phyllopoden der deutschen Unterkarbons: Preuss. Geol. Landesanstalt, Abh., n.f., no. 194, 107 pp., 7 pls., 20 figs., 1939. (See esp. pp. 7, 79.)

Ostracodes in the Lower Carboniferous are most abundant in argillaceous limestones or marls, less so in siliceous sediments. They avoid the coarser sediments (sandstone, conglomerates), and also the crystalline part of the limestones. The shells are best preserved where rapid and undisturbed sedimentation occurs.

Ostracodes are good index fossils because of their frequency of occurrence and independence from rock facies. They occur not throughout a thick stratum but rather in certain, sharply-defined zones. A large fauna appears suddenly and disappears again, often with no apparent marked petrographic change.

Ostracodes are not indifferent to the life conditions of the environment, as is so frequently stated. On the contrary, from all the evidence available the benthonic individuals are limited by the oxygen and food content, and by the consistency of the ocean floor. These factors as well as the difficulties in preservation of the thin pelagic shells, effects a strong variation in the frequency of the occurrence of fossil ostracodes, as well as a predominance of benthonic forms.

A comprehensive survey of the Paleozoic ostracodes in Europe shows that, as in Recent time, nektonic and benthonic individuals permit differentiation. The benthonic species, furthermore, permit classification as creeping, as near-floor swimming, or as attached forms. Final criteria include the shell structure as well as the type of rock occurrence. Strictly speaking, planktonic and consequently passive swimming ostracodes are not present in the Paleozoic, even as they are not in the Recent.

The principal representatives of the nektonic ostracodes in the Paleozoic are the entomids--forms with thin chitinous shells having little or no calcareous elements for strength, and yet having such swim-hindering structures as tubercles, ridges, spines, and brood pouches. Also, the cypridinids and entomoconchids have very thin slightly calcareous shells, equivalved. In addition, Graphiodactylus and others, singularly Devonian forms whose systematic place is not yet truly known, conform to this description. These factors show that the individuals lived in clear water rather than in the realm of a muddy floor, and they are borne out by the rocks in which these individuals occur.

It is commonly supposed that the fossil planktonic and nektonic organisms depended somewhat upon the rock facies, as is true of bottom-dwellers. However, the nektonic forms actually occur in all generally ostracode-bearing rocks, yet show a decided preference for clay shales and dark bituminous limestones, in which they occur either alone or with nektonic individuals.

Benthonic ostracodes, such as Monoceratina, are characterized by thick, strongly calcareous shells, closed all the way around, and with richly-

developed surface sculpture as a preventive against sinking in the ooze. Smooth-shelled or weakly-sculptured forms are not capable of wandering over the sand, but slide around. The conclusion is that the sculptured forms are bottom-dwelling.

However, sometimes Leperditacea, Beyrichiacea, and Cypridacea, having similarly thick but smooth shells with only slight grooves and keels, occur in dominance in similar rocks.

The thick-shelled and smooth ostracodes, which occur especially in marly rocks, have not led a crawling life, but probably lived swimming in near floor waters, or attached to water plants. This group includes all the larger ones, the Leperditiidae.

Benthonic ostracodes, although not especially affected by the lack of oxygen, prefer the fresh (oxygen-rich) floors. Thus they are most common in marly rocks and impure limestones, but are absent from shale and limestone with a large amount of pyrite and bitumen. Their frequency rises until a certain shaliness is reached, beyond which they decline in number.

In pelagic ostracodes the protective function of the shell diminishes and the shell is thin.

Kummerow, E. H. Egmont

Über Lebensweise und stratigraphische Bedeutung der Ostracoden: Zentralblatt Mineral., Geol., Paleon., Abt. B., No. 5, pp. 121-128, 3 figs., 1940.

H. Schmidt (1935, p. 65) has shown that the grain size of the sediments on the continental shelf, the chief life province of ostracodes, does not diminish with increasing distance from the shore, but that this only seldom occurs. He found that there is a patchy arrangement of sediments, without apparent relation to the shoreline or to the outer margin of the shelf, and that the finer muds are often deposited near the strand in protected places. Thus there is a rapid and irregular change in rock character and fossil occurrence which differs from the supposed zonal arrangement.

Loomis, F. B.

The dwarf fauna of the pyrite layer of the horizon of the Tully limestone in western New York: New York State Univ. Bull. 303 (New York State Mus., Bull. 69, Paleontology, 9), pp. 892-920, pls. 5, 10-14, 1903. (See esp. p. 899.)

Shallow water, perhaps landlocked in part, and undoubtedly running shoreward into low, coastal marshes. The waters were surcharged with iron and the bottom was filled with decaying organic matter. This was not the environment for normal growth. However, the ostracodes are not particularly dwarfed.

Merrett, Edgar A.

Fossil ostracoda and their use in stratigraphical research: Geol. Mag., vol. 61, pp. 228-238, 1924. (See esp. p. 229.)

The easy scattering of the shells after death by waves or currents, and by the wind makes caution necessary in ascribing the forms to certain environments, though it is true that forms swimming on the surface are distinctly different from those creeping on the bottom. Further, the fresh-water forms are distinct from marine. If no marine forms are found, the deposit is probably fresh-water, whereas fresh-water forms may be carried to a final resting place with marine deposits.

Monahan, Joseph W.
Studies of the fauna of the Bertie formation: Am. Midland Naturalist, vol. 12, pp. 377-400, 1931. (See esp. p. 382.)

The ostracodes (Leperditia) in the Williamsville waterline are probably normal marine forms--stragglers from another environment. The deposit is not deltaic, but rather from the seaward side of the reef, deposited in the widespread lagoon conditions to the landward of an epicontinental reef. The ostracodes are crammed onto the eurypterids--probably as scavengers.

Öpik, A.
Ostracoda from the Old Red Sandstone of Tartu, Estonia: Tartu Ülikooli Geoloogia--Instituudi Toimetused no. 45, (Ann. Nat. Soc. Tartu Univ., vol. 42, pp. 20-27.) 8 pp., 2 pls., 6 figs., 1935.

The ostracodes occur in calcareous and dolomitic, fine-grained sandstone, associated with fishes. In the more pure sands and clays, the preservation is bad. All the Ostracoda are doubtlessly marine. The origin of this faunule is not clear, but probably it is connected with a marine transgression into the Old Red area.

Ruedemann, Rudolph
The Paleontology of arrested evolution: New York State Mus. Bull. 196, pp. 107-134, 1918.

The more persistent organisms are those of the lower classes, sessile, marine. Small forms are more persistent, as are those which have a slow development, a distinct climatic period, and a long post-climatic one (Bairdia). Scavengers persist.

Schmidt, Hermann,
Die bionomische Einteilung der fossilen Meeresböden: Fortschritte Geologie und Palaeontologie, Bd. 12, H. 38, 147 pp., 24 figs., 1936.

The ostracodes lived in the Paleozoic, as today, more abundantly in the near-floor area of the sea, especially in the protection of vegetation. However, in the Cypridinid-shale (Upp. Dev.), Entomis and Richterina are so evenly distributed over wide and bathymetrically distinct zones as to suggest planktonic life.

Scott, Harold W.
Permian and Pennsylvanian fresh-water ostracodes: Jour. Paleontology, vol. 18, pp. 141-147, pls. 23-24, 1 fig., 1944.

Fresh-water ostracodes are rare in the Paleozoic because of the environment in which they lived, although they were probably much more abundant in the ponds and lakes of the Paleozoic than the few fossil remains would indicate. The limestones are very argillaceous to pure, and are mostly unfossiliferous, but locally contain ostracodes in considerable numbers. Often associated with Spirorbis. The lakes and ponds were very shallow, warm, and there floors were covered with mud, decayed vegetable matter, and algae.

Scott, Harold W.
(and Summerson, Charles H.) Non-marine Ostracoda from the Lower Pennsylvanian in the southern Appalachians, and their bearing on intercontinental correlation: Am. Jour. Sci., vol. 241, no. 11, pp. 654-675, 2 pls., 1943.

The distribution of certain species and genera may be controlled by independent factors such as bottom, current, or hydrogen-ion concentration. The Candoninae are essentially bottom crawlers and prefer a mud bottom to a sand and gravel floor. Candona and Cypridopsis lived in a very shallow water, in permanent, still water with a luxuriant aquatic flora.

One occurrence, in a canneloid shale at the top of a cannel coal, showed the tests well-preserved in pyrite. This suggests an abundance of sulfide, a condition characteristic of black shale environment. Associated with the ostracodes are leaf fragments, stems, fruiting bodies, pelecypods, Spirorbis, and fish remains.

Shrock, Robert R.
Stratigraphy and structure of the area of disturbed Ordovician rocks near Kentland, Indiana: Am. Midland Naturalist, vol. 18, pp. 471-531, 5 pls., 8 figs., 1937. (See esp. pp. 512-515.)

Fossils are abundant in the upper sides of the layers, which are largely comminuted shell matter, apparently macerated by scavengers and fragmented by waves, whereas the well-preserved fossils on the upper sides of the layers were saved by an influx of mud which buried them instantly, as evidenced by the shale partings.

Spizharsky, T. N.
Ostracoda from the Kolchugino series (Carboniferous) of the coal-bearing strata of the Kuznetsk Basin (Russia): Central Geol. and Prospecting Institute, Tr., F. 97. pp. 139-171, 2 figs., 1 pl., 1937 (English summary). (See esp. p. 165.)

The fauna developed in a closed, brackish-water basin.

Swartz, F. M.
Silurian and early Devonian studies in the middle Appalachians: New York Acad. Sci., Trans., ser. 2, vol. 4, no. 6, pp. 177-190, 1942. (also in Pennsylvania State College Min. Industries Experiment Sta., Tech. paper 76, 1942.)

In general the shelly assemblages lived in shallow reaches of the sea, mostly in waters not continuously clear, and perhaps a little brackish.

Thorslund, Per

On the Chasmops series of Jemtland and Soderlaland (Tvaren) (Sweden): Sveriges Geplogiska Undersokning, sc. no. 436. (Arsbok 34, no. 6), 189 pp., 56 figs., 15 pls. 1940. (See esp. pp. 49-80.)

The reef-like limestone is rich in ostracoda, but this is not true of the shaly facies, which has only Steusloffia. The limestone beds usually seem to be shallower water deposits than the shaly beds.

Ulrich, E. O.

The Ostracoda as guide fossils in the Silurian deposits of the Appalachian region (abst.): Geol. Soc. America Bull., vol. 28, p. 202, 1927.

The same species occurs indiscriminately in limestone, shale, or sandstone.

Ulrich, E. O.

(and Bassler, R. S.). Paleozoic Ostracoda: Their Morphology, Classification, and Occurrence: Maryland Geol. Survey, Silurian volume, pp. 271-391, 1923. (See esp. p. 279.)

Free swimming forms today are indicative of well-lighted areas, while those less able to swim spend most of their existence in the slimy debris and ooze of the bottom. Some live indefinitely in very foul waters, as in sewers, other living in sulphur water and in hot springs. Practically none are found in pure cold spring water or well water. Thus they thrive under conditions usually regarded as unfavorable, but because of the smallness and lightness of the shells they were swept along by waves and currents to places they did not inhabit. Thus they are found in all kinds of sediments, whether sandstone, shale, or pure limestone. They are both swimmers and bottom-dwellers.

Upson, M. E.

The Ostracoda of the Big Blue series in Nebraska: Nebraska Geol. Survey., 2nd Ser., vol. 8, 54 pp., 4 pls., 1933.

Ostracodes are more abundant in the shales, in shaly seams within the limestones, and in the soft, shaly limestones; they are less abundant in hard limestones and sandstones.

Volk, Max

Das Oberdevon am Schwarzburger Sattel zwischen Südrandspalte und Kamm des Thüringer Waldes: Phys.-med. Soz. Erlangen, Sber. Bd. 70, pp. 147-278, 5 figs., 3 pls., 1939.

Ostracodes are common in the interbedded calcareous sandy layers, rare in the pure clay shales. The more nodular the limestone, the less common the ostracodes.

ADDITIONAL JAPANESE REPORTS[8]

by

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The Marine Biological Stations of Japan together with other scientific institutions are making courageous efforts toward reorganization, in part for economic ends such as the fisheries, oyster, especially seed osyter, culture and pearl culture. The Akkeshi Laboratory in southeastern Hokkaido, under the direction of the Hokkaido University at Sapporo, is probably the largest and the best equipped and has not suffered recent damage. The Asamushi Marine Biological Station on Mutsu-wan in northern Honshu, under the Tohoku University in Sendai, was partially flooded by the high water in the summer of 1947. The Station on Wakasa-wan, associated with Kyoto University, was disrupted by the earthquake earlier in the same year; much of the equipment was lost and the alcoholics broken. The Station under Tokyo University on Chiba Peninsula, that under Hiroshima University near Onomichi and the Station under Kyushu University near Nagasaki are all active.

The following notes are not comprehensive but are indicative of the work in progress:

Studies of the bottom faunas in the larger and smaller bays that fringe the Japanese coast have been under way for a number of years. Those covered by the present report were made in whole or in part by Denzaburo Miyaji of the Seto Marine Laboratory of the Kyoto Imperial University. Tetsuo Masui was associated with him in the work on Nanao and Matoya and Gokasyo Bays, and Tadasige Habe on the general report. The reports are, to be sure, concerned primarily with the ecology of the living benthos but the ecologic conditions and the process of accumulation of organic remains in the present are doubtless a repetition of those of the past.

The northernmost bay, Nanao-wan, is only a little above 37° N. lat. and Tanabe-wan, the southernmost, is about 33°40'. The general conditions are sufficiently similar so that we may look for explanations of faunal differences and resemblances in the individual characters of the bays.

Miyaji, Denzaburo

1. Marine benthic communities of the Tanabe-wan: Annotationes Zoologicae Japonenses, vol. 19, no. 2, pp. 136-148, 5 tables, 3 text figs., June 15, 1940. (In English.)

2. Marine benthic communities of the Osaka-wan: Journal Oceanography, vol. 12, no. 2, pp. 371-385 [1-15], 3 tables, 2 text figs., 1940. (In English.)

8/ Translated and abstracted by staff of Pacific Island Mapping Program, Military Geology Section, U. S. Geological Survey.

Miyaji, Denzaburo

3. Ecological survey of the Benthos of the Ago-wan: Annotationes Zoologicae Japonenses, vol. 20, no. 3, pp. 169-180, 4 tables, 1 text fig., 1941. (In English.)

4. Identation individuality in the Tanabe-wan: Imp. Marine Observatory, vol. vii, no. 4, pp. 471-482, 5 tables, 3 text figs., March 1941. (In English.)

5. Marine benthic communities of the Ise-wan and the Mikawa-wan: Imp. Marine observatory, Memoris, vol. vii, no. 4, pp. 503-524, 7 tables, 6 text figs., March 1941. (In English.)

Miyaji, Denzaburo and Masui, Tetsuo

1. Comparative studies of the marine benthic communities of Matoya Bay and Gokasyo Bay in Miye Prefecture: Japan Society Scientific Fisheries, Bull., vol. 2, no. 3, pp. 111-127, 9 tables, 6 text figs., September 1942. (In Japanese; no abstract.)

2. Studies of the benthic communities of Nanao Bay: Japan Oceanographic Society, vol. 2, no. 1, pp. 1-21, 9 text figs., November 1942. (In Japanese; no abstract.)

Miyaji, Denzaburo and Habe, Tadasige

On thanatocoenoses of bays: Physiology and Ecology, vol. 1, no. 2, pp. 110-124, tables 1-4, 1947. (In Japanese; abstract in English.)

Ise-wan and Osaka-wan on either side of the Kii Penisula are the largest of the bays. The water from the Pacific enters Ise-wan through a single narrow and tortuous strait. Islets and reefs of various sizes act as additional breakwaters, and any gravel or coarse sand carried by the waves is laid down near the mouth of the bay. In the middle of the bay is a distinct depression isolated by the 30 m depth contour. Mikawa-wan, the secondary bifurcated bay on the eastern shore near the entrance, rarely exceeds 16 m in depth. A number of rivers enter Ise and Mikawa-wan and greatly influence both the average and the seasonal oceanographic conditions, especially the oxygen content. The pollution of the water near Nagoya at the head of Ise-wan is less obvious than that near Osaka and Kobe.

Osaka-wan, though farther inland, is a fairly regular ellipse, opening both at the lower end and to the west. The tidal current between the two narrow entrances is strong and the depth may exceed 100 m. In the northeastern part of the bay, however, it is less than 20 m. The nature of the bottom is fairly complex; coarse materials prevail along the paths of the currents, black and more or less polluted soil in the northeastern area, especially near the great harbors of Kobe and Osaka; and, in most of the other areas, a grayish soil with a soft surficial brown layer. The benthic communities recognized in the two bays differ conspicuously.

The following four associations were recognized in Ise-wan:

1. Prionospio association. A large spiniform polychaete occupies the muddy bottom of the basin-like central part of the bay. The same annelid occurs

under the same conditions in Beppu-wan. The only living mollusk taken was Theora lubrica.

2. Pinnixia association. A small but adult crab made up more than 41 percent of all animals collected in Ise-wan. It was collected on gravel, sand, and sandy mud bottoms but never on mud. The association must have been tempoary, possibly seasonal, for it was too prolific to occupy the bottom for long. A number of Mollusca were also present but not in conspicuous numbers, except for Volsella compta on a restricted sand bottom on the western margin of the bay.

3. Ampelisca-Theora lubrica association. An amphipod and bivalve characterize a varied coastal assemblage and a typical shallow-bottom community, including a number of mollusks, both bivalves and univalves, and echinoids and starfish. The bottom character ranges from mud to mud with fine sand or shells.

4. Sclerocheilus association. A polychaete with a club-shaped body is prominent on the mud and fine-sand bottom near the mouth of Ise-wan. Other polychaetes and a few mollusks and echinoids were also present.

Commonly life is more abundant in the secondary bays than in the main bay, but the benthic faunas in Mikawa-wan are relatively poor because of the small drainage area and the relatively small amount of food brought down by the streams. Both conditions and faunas are similar in the north and east coasts of Ise-wan and in Mikawa-wan. In Osaka-wan, polychaete worms make up 61.3 percent of all the animals collected. The most abundant forms are usually detritus or suspension feeders for no carnivors can be dominants for long.

The following three associations were recognized:

1. Lygdamis community. Near the straits, both Akasi and Tomogasima, the bottom is swept by the current and strewn with coarse sand, gravel, and shell fragments, remarkably clean and free from silt. These materials have been patched by a tubicolous annelid into durable tubes, which prevail from 100 m to 40 m and rarely to 26 m. Ophiurans are relatively common associates and holothurians, crabs, shrimps, and a few Mollusca are locally present. The area is the most productive fishing ground of Osaka-wan.

2. Telepsavus community. Another polychaete which builds a long chitinous tube occupies a considerable part of the northeastern area and is most abundant near the outer margin of the black mud; probably the tube enables the animal to extend its breathing organs above the polluted zone. The same device may be used by the associated bivalves such as, Theora lubrica and Macoma. A few shrimps, and the sea star Astropecten are also present.

3. Bechelia community. A holothurian, Bechelia dubia, is the most common occupant of the silty bottom, 18 to 54 m down on the western margin and along a north and south strip in the middle of the basin. It is a typical detritus feeder and, like other holothurians and ophiurans, avoids a polluted feeding ground.

Four smaller bays which indent Kii Peninsula have been studied: Matoya-wan, Gokasyo-wan, and Ago-wan at the eastern extremity of Miye Prefecture and

Tanabe-wan, south of Osaka-wan, more than halfway down the southwest coast of Wakayama Prefecture. Inner Bays, not in direct contact with the sea water, commonly shelter faunas distinct from those of the outer bay. Matoya-wan is a drowned valley. A narrow tortuous channel connects it with Izo-no-ura, an inner expansion from 1 to 4 m deep. The greater part of Matoya-wan is less than 10 m deep, though it may reach 20 m; the channel is intermediate in depth and characters. The entrance to the bay is floored with coarse sand and the main basin with fine sand and sandy mud. In the greater part of the main basin and in the channel where the current is rapid, ascidians are numerous, and Eugyrioides-Caprella the typical association. It is similar to the community in the North Bay of Nanao-wan and represents the area of maximum circulation of the sea water and the richest plankton. Maldane and Terebelloides are abundant in the greater part of the channel and indicate a fairly strong bottom current; the same community is found among the reefs in the main basin of Ago-wan. Brachydontes, Loripes, and Macoma thrive only on the mud bottom. The fauna of the inner bay is dominantly molluscan.

Gokasyo Bay is an ill-defined inner bay with poorly differentiated benthic communities. The ratio of Mollusca increases with the increase in definition of the bay characters and the ratio of the Crustacea decreases.

Ago-wan is the most ragged section of the southeastern coast of Kii Peninsula. It is famous for its pearl culture, and practically every protected corner of the bay is occupied by pearl oyster rafts. The bay waters are usually less than 15 m deep except for the furrows between the reefs, in which a depth of 40 m is recorded. In spite of the large number of natural breakwaters, the circulation in the bay seems reasonably good. Near the mouth of the bay, the bottom is sand and gravel; gravel is also common in the central part of the bay, though the greater part of the bottom is muddy. Black mud is restricted to the heads of the inlets and is topped with a brownish fluff of oxidized sediments. Zostera is growing in a few restricted areas.

The benthic communities include, first, a molluscan fauna, a rich and varied coastal assemblage, for the most part bivalves, living on the sand and mud bottoms; Paphia undulata is, as elsewhere, restricted to the heads of the inlets where the black mud is covered with a brown surface layer rich in organic debris. The second assemblage, the Terebelloides-Maldane polychaete association, occupies the mud bottom 15-40 m deep in the furrows between the reefs where the circulation is best and the inflow of sea water strongest.

The submerged reefs and erosion platforms are colonized by sedentary plankton feeders.

Nanao-wan, the most northern of the bays and the only one opening on the Japan Sea, indents the eastern coast of Noto Peninsula, Ishikawa Prefecture. It is well suited to an ecologic study for it includes three well-characterized basins - North Bay, West Bay, and South Bay. North Bay is the largest and deepest of the three. The coastal dip is steep and the 20 m isobath is close to shore; the strip between 25 m and 40 m, however, is wide. The entrance to the bay is also wide, allowing a free interchange of ocean and bay water.

The composition of the benthic community includes about 55 percent polychaetes, 20 percent Crustacea, and 11 percent Mollusca. The dominant group in North Bay is the ascidian, and, as in the main basin of Matoya-wan, Carprella is conspicuously abundant.

West Bay is the smallest and the most shallow of the bays of Nanao-wan, but it is a food reservoir for North and South Bays. Plankton and sapropel are supplied from it, and Zostera is abundant within a limited area. About half of the bay is less than 5 m deep, but a narrow trench, apparently due to current action, is cut in the connecting strait. The rule that the increase in Mollusca and the decrease in Crustacea is in direct relation, as a rule, to the development of the inner bays is observed in Nanao-wan. In West Bay the percentage of Mollusca is 65; of polychaetes, 12.5; of Crustacea, about 10. The Brachydontes-Theora fauna is characteristic of the muddy West Bay bottom, and with it are associated a number of small gastropods and bivalves. South Bay is intermediate in character between North and West Bays. The percentage of Mollusca is 53.8; of polychaetes, 29.4; of Crustacea, only 7.5.

Nanao-wan is a favorite breeding ground for fish because of the varied ecologic character.

The final paper, by Miyaji and Habe, is concerned with the dead shells in the bays and their accumulation. A number of fossil species are found living, many of them in characteristic and restricted habitats in the Japan bays. Among such forms are Ditrupa edoenis, Loripes yamakawai, and Thyasira rotundata, associated with mid-bay faunas; and Mysella oblongata and Stenothyra edogawaensis characteristic of inner bays. Some of the species shift, Ditrupa edoensis, for example, which lives at the mouth of the branch bays in November but shifts toward the center of the bay in the summer. Observations must be made over a period of years to be sure of the significance of the apparent seasonal migrations of certain species. The number of species is relatively large at the mouth of the bays, but the number of individuals is greater in the inner bays. Pteropods are good indicators of the proximity of the open sea, but pteropods in quantity have been found in the bays, driven in by high winds and waves. In general, however, the transportation of shells by tidal currents is unimportant. Shells which have an adaptation to a special environment usually live in large numbers with little competition and, if there is any change in the environment, they die in large numbers. A few bivalves but no gastropods are able to live in the reducing mud, possibly because by means of their siphons they are able to reach a zone with a higher oxygen content. The black reducing mud is particularly favorable to their preservation. If no outer forces are acting, the area of accumulation of the dead shells corresponds to the maximum area of distribution of the living shells.

ALGAE IN RECENT AND ANCIENT REEFS

by

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Lithology of marine reefs is determined primarily by the organisms which build them. Coral reefs are the best known examples of reefs, Recent and fossil. Because reef-building corals are familiar large organisms, they are readily identifiable in the field, and the manner in which corals build reefs can be observed with comparative ease. The characteristic features, which enable these organisms to build a complex, coherent, and durable structure, which is called a reef, are: (1) their strong calcareous skeletons, (2) large size, and (3) erect growth and branching which is due to vegetative propagation by budding, which produces shrub-like entanglement of branches. The study of modern reefs, notably Funafuti and others in the southern Pacific, has shown, however, that calcareous algae, and not corals, are the most abundant organisms in many reefs. Even in those reefs where corals predominate, the latter are such an important element that it is believed (Setchell, 1926; Foslie, 1907; Howe, 1932; and others), reefs could not have been built without the help of algae.

Among the characters that seem to make algae so important, and apparently even indispensable, in the building of reefs are: (1) their tight adherence to corals and other sedentary animals occurring on the reefs, and (2) their spreading, in the form of encrustations and branches, over and between the corals, thereby binding the corals and other organisms into a solid mass. Such binding appears to be the decisive factor that makes the existence of reefs possible. Some modern reefs are built almost entirely by algae, and no reefs are known which are built without their substantial aid along their fringes (Foslie, 1907; also in review by Goldring, 1938).

Encrusting sedentary Foraminifera are next in importance to algae and corals in the building of modern reefs. Other organisms, including various mollusks, some green algae (Dasycladaceae), sponges, some brachiopods, and some crinoids, live in the shelter of growing reefs, but add little if anything to the coherence or strength of the reefs. Most of these line the bottoms and walls of caves and passages within the reefs.

Fragments of all the plants and animals found in the reefs, together with some inorganic debris, such as sand and silt, fill the bottom of caves and passages, and accumulate upon the slopes and lagoons of coral reefs. Also, some inorganic lime is precipitated in crusts over dead organic surfaces, and fine lime muds and floccules are deposited.

The combination of reef-building and reef-sheltered organisms, inorganic encrustations over them, and debris accumulated inside and outside of the reefs, produces lithologic features peculiar to reefs. Subsequent processes of mineralization and recrystallization, that is, diagenesis, tend to obliterate

these original features and make their recognition difficult. In many cases diagenesis appears to have produced unfossiliferous structureless massives, whose reef origin is usually recognized by the relationships of the surrounding ordinary marine deposits deposited contemporaneously (Blackwelder, 1913; Walther, 1885; Johnson, 1937; also in review by Goldring, 1938). Dolomitization has occurred in many reefs resulting in localized (spotted) porosity, thus making reef structures excellent reservoirs for petroleum. Examples of this type of alteration are illustrated in the late Carboniferous and early Permain "shikhany" of the western and southern Urals in Russia (Sermjaghin, 1939; Shamov, 1940; Trofimuk and Dubrovin, 1936), and in reefs of about the same age and similar structure in southern New Mexico and adjacent parts of Texas (King, 1932; and others).

The Permian reefs of the Glass Mountains and the adjacent area have been described by many geologists, but their natural history and subsequent diagenesis need much additional study. Similar reefs of the Urals in Russia are better known in these respects. These "shikhany" were built primarily by Bryozoa, and therefore are called "bryozoan reefs." Corals are insignificant, but algae are mentioned as occurring in abundance in some of them (Trofimuk and Dubrovin, 1936). The reef-like Permian limestones of the Glass Mountains were apparently also built primarily by Bryozoa, with corals and known algae playing an insignificant role. Other fossil reefs, in which Bryozoa are abundant, and which are called "bryozoan reefs," have been known to geologists for a long time. They range in age from Silurian (and possibly Ordovician) to Tertiary (Andrussow, 1912). A problem is posed: were these fossil bryozoan reefs built without the aid of encrusting calcareous algae, that to our best knowledge are indispensable in building modern reefs? Or were algae present that have so far escaped our scrutiny? An answer to this is seemingly provided by the recent studies of late Paleozoic Bryozoa which have been conducted at the Nebraska Geological Survey since 1940.

In 1944 Condra and Elias published their "Study and Revision of Archimedes (Hall)." wherein they advanced the theory (chief responsibility for which is assumed by Elias), that the solid encrustation, which builds the massive screw of Archimedes, the lyre-like arms of Lyropora, and so-called appendages in these and other fenestrate Bryozoa, are not integral parts of the bryozoans and are not produced by them, but belong to a different, plant-like organism. Condra and Elias called this organism a "phytomorph," for the sake of discussion. Various features of the phytomorphs were illustrated, described, and discussed in some detail in the paper, and their similarity to various living algae were pointed out. It was concluded that the phytomorphs lived with the fenestrate bryozoan Fenestella symbiotically, to mutual advantage, thus enabling this genus to produce larger, healthier, and more durable growth forms. It was further concluded that the genus Archimedes was a stablized growth form of Fenestella and the phytomorph, in other words, a consortium (a "wedlock") of these two marine organisms.

Another example of a consortium of the fenestrate bryozoan Polypora and a phytomorph was described by Condra and Elias in 1945 as Bicorbis (name later changed to Bicorbula) from the Permian Kaibab limestone of Grand Canyon, Arizona. The phytomorph in this consortium is apparently related to the living red algae

Marchessettia and Liagora from the Southern Pacific. A summary of the evidence pointing out the existence of "Symbiotic Fossil Algae in Comparison with other Fossil and Living Algae" was published by Elias in 1946.

In the writer's opinion the evidence indicates that encrusting and branching algae played as essential a part in the building of bryozoan reefs in the geological past as they play in the building of modern coral reefs. Difficulty in recognizing their algal nature is due to the fact that they lived in intimate symbiotic contact with nearly all fenestrate bryozoa and are believed to be an integral part of them. Additional comparative studies of fossil and recent reefs and of the role of algae, Foraminifera, Bryozoa, corals, and other organisms in their structure and growth seem important and timely, both for basic scientific data and for their application in the field of economic geology.

References

Alexandrova, E. P. — On the diagenesis in the Upper Paleozoic reef limestones from the western slope of Urals: Trans. of the Geological Oil Institute, Ser. A, Fasc. 115, pp. 188-205, 2 text-figs., 3 pls., 1939.

Andrussow, N. J. — Die fossilien Bryozoenriffe der Halbinseln Kertsch und Timan. 1912.

Blackwelder, E. — Origin of the Bighorn dolomite of Wyoming: Geol. Soc. America Bull. 24, pp. 607-624, 1913.

Condra, G. E. and Elias, M. K. — Study and revision of Archimedes (Hall): Geol. Soc. America Spec. Paper 53, 243 pp., 6 text figs., 41 pls. 1944.

_____ — Bicorbula, a new Permian bryozoan, probably a bryozoan-algal consortium: Jour. Paleontology, vol. 19, pp. 116-125, pls. 13-16, 1 text fig., 1945.

_____ — Bicorbis arizonica Condra and Elias, new name for B. arizonica: Jour. Paleontology, vol. 19, p. 411, 1945.

Elias, M. K. — Fossil symbiotic algae in comparison with other fossil and living algae: Am. Midland Naturalist, vol. 36, pp. 282-290, 2 pls., 1946.

Foslie, M. — The Lithothamnia: Linnean Soc. London, Trans., Zool., 2d ser., vol. 12, pp. 177-192, pls. 19-20. 1907. (Quotes Gardiner, S., pp. 177-178, on importance of Nullipores in coral reefs).

Goldring, W. — Algal barrier reefs in the Lower Ozarkian of New York, with a chapter on the importance of coralline algae as reef builders through the ages. New York State Museum Bull. 315 (Chapter on the importance of coralline algae, pp. 51-67; bibliography, pp. 67-74). 1938.

Heydrich, F. — Corallinaceae, insbesondere Melobesieae. Berichte d. deutschen botanischen Gesellschaft. Bd. 15, Ht. 1, pp. 34-70, pl. III, text-figs. 1-3, 1897.

_____ — Melobesias. Ibid., pp. 403-420, Pl. XVIII, 1897.

Howe, M. A. — The geologic importance of the lime-secreting algae: U. S. Geol. Survey Prof. Paper 170-E, pp. 57-69, pls. 19-23, 1932. (Includes review on role of algae in "coral" reefs.)

Johnson, J. H. — Algae and algal limestones from the Oligocene of South Park, Colorado: Geol. Soc. American Bull. 48, pp. 1227-1236, 1 fig., 2 pls., 1937.

King, P. B. — Limestone reefs in the Leonard and Hess formations of trans-Pecos Texas: Am. Jour. Sci., 5 ser., vol. 24, pp. 337-354, 4 figs., 1932.

Sermjaghin, B. — Lithology of the Upper Paleozoic reef limestones from the western slope of Urals: Trans. of the Geological Oil Institute, Ser. A, Fasc. 115, 117-188, 1939.

Setchell, W. A. — Nullipore versus coral in reef formation: Am. Philos. Soc. Proc., vol. 65, pp. 136-140, 1926.

Shamov, D. F. — On geological structure of Ishimbaievo oil-bearing region: Soviet Geology, vol. 8, no. 11, pp. 6-20, 3 text figs., 1940.

Trofimuk, A. A. and Dubrovin, A.N. — On the nature of the oil-bearing limestone massifs of Ishymbaeveo: Problems of Soviet Geology, vol. 6, no. 11, pp. 952-977, 8 text-figs., 1936.

Walther, J. — Die gesteins bildenden Kalkalgen des Golfes von Neapel und die Entstehung structurloser Kalke: Zeitschr. d. deutschen geol. Gesellschaft, vol. 37, pp. 329-357, 1885.

A COMPARATIVE STUDY OF THE FOSSIL FORAMINIFERAL FAUNA OF THE RYUKYU LIMESTONE AND THE RECENT FAUNA OF THE RYUKYU ISLANDS

by

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1. Ryukyu Limestone, Ecological Condition under which it was Deposited, and its Geological Age.

As already stated by me (1935, p. 14), the Ryukyu limestone is extensively developed in the Ryukyu Islands and the southern extremity of Formosa. It rests upon the Middle Permian, Upper Eocene, Lower Miocene, and Pliocene formations with marked unconformity in the former islands and on the Upper Eocene and Pliocene sediments with an angular unconformity in the latter, and is usually covered with Pleistocene terrace gravels in both the regions. This limestone is horizontal in the Ryukyu Islands and Formosa, but sometimes it is tilted together with the overlying gravel in the latter region. As it suffered subsequent erosion, it is difficult to determine its original thickness. Its maximum thickness is estimated, however, to exceed scarcely 100 m. The Ryukyu limestone is white or light yellow and contains numerous coral reef organisms, such as reef-building and ahermatypic corals, Foraminifera, Bryozoa, Brachiopoda, Mollusca, Echinoidea, and calcareous algae. The organic content of this limestone varies in different localities, Foraminifera preponderating in some places and reef-building corals in others. I believe that anyone who studies the occurrence of the fossils of this limestone, will readily notice that the content of reef-building corals in this limestone is small compared with its wide extension, while the Foraminifera are, on the contrary, usually abundant everywhere. Not only the tropical and subtropical shallow water larger Foraminifera, such as Acervulina, Amphistegina, Baculogypsina, Calcarina, Heterostegina, Homotrema, Miniacina, Operculina are common in this limestone, but also Alveolinella quoyi (d'Orbigny), Baculogypsinoides spinosus Yabe and Hanzawa, and Cycloclypeus carpenteri Brady are ubiquitous and conspicuous species in it.

Formerly, I presumed that the Ryukyu limestone was formed under a climate somewhat warmer than that now prevailing in the Ryukyu Islands chiefly because I was unaware of the occurrence of Baculogypsinoides spinosus Yabe and Hanzawa in any of the seas north of the Philippines and also notwithstanding an alcyonarinan coral, Tubipora rubiola Quoy and Gaimard is found in the limestone as far north as Kikai-jima. I have failed to find this genus or species living in the seas of the Ryukyu Islands, although this species is found in Formosa and the Bonin Islands. But, I know now that the fossil foraminiferal fauna of the Ryukyu limestone is similar to the Recent fauna of the same region. Moreover, as stated below, the recent bathymetrical distribution of the dominant species, such as Cycloclypeus carpenteri Brady, Alveolinella quoyi (d'Orbigny), and Baculogypsinoides spinosus Yabe and Hanzawa clearly indicates that the greater part of the Ryukyu limestone was deposited as calcareous sediment in a neritic zone, but not in a littoral zone where the reef-building

corals thrive. However, a part of the Ryukyu limestone was formed as a number of fringing reefs in the Ryukyu Islands and Formosa. Although Amphistegina radiata (Fichtel and Moll), Baculogypsina sphaerulata (Parker and Jones), Calcarina spengleri Linnaeus, Heterostegina depressa d'Orbigny, Homotrema rubrum (Lamarck), Miniacaina miniacea (Pallas), Operculina ammonoides (Gronovius etc., cited above are also common species of this limestone, they have a wide bathymetrical range from the littoral zone to many hundreds of meters in depth. Therefore, I have used only Cycloclypeus carpenteri, Alveolinella quoyi, and Baculogypsinoides spinosus, which have a limited bathymetrical range, in studying the ecological conditions under which the Ryukyu limestone was deposited.

As to the geological age of the Ryukyu limestone, H. Yabe and I (1925, p. 37) formerly assigned it to the Upper Pliocene or Lower Pleistocene, although S. Nomura and N. Zinbo (1937, p. 111), from their study of the fossil Mollusca, provisionally regarded the Ryukyu limestone as the lowest Pleistocene in age on the basis of the low percentage of extinct species.

I now believe that the Mariana limestone of the South Mariana Islands and the Palao limestone of the Palao Islands in the southwestern North Pacific may safely be correlated with the Ryukyu limestone upon paleontological, stratigraphical, and geomorphological points of view. The Palao limestone is likely to be considered as Pleistocene in age rather than Tertiary, as stated in my forthcoming paper entitled "Cenozoic Foraminifera of Micronesia," now in press.

2. Calcareous Marine Sediments Obtained by the S. S. MATSUYE, Surveying Ship of Japan in 1926 from the sea adjacent to the Miyako and Yaeyama Subgroups of the Ryukyu Islands.

Descriptions of the Samples

1) Lat. 24° 11'22"N; Long. 123° 27'14"E; depth 87 m. West of Iriomote-jima. CALCAREOUS SAND: Coarse, granular, apparently washed; consists of coral fragments, encrusting Foraminifera, Bryozoa, and calcareous algae. The Foraminifera are

Cycloclypeus carpenteri Brady	present
Baculgyosinoides spinosus Yabe and Hanzawa ?	present
Amphistegina radiata (Fichtel and Moll)	present
Homotrema rubrum (Lamarck)	present

2) Lat. 24°12'34"N; Long. 123°27'19"E; depth 96 m. West of Iriomote-jima. CALCAREOUS SAND: Apparently washed, consists of microspheric specimens of Cycloclypeus carpenteri Brady and Lithothamnion concretions.

3) Lat. 24°15'02"N; Long. 123°07'06"E; depth 133 m. South of Yonaguni-jima. CALCAREOUS SAND: White; granular, quite incoherent, has the appearance of having been washed; contains the following species of Foraminifera:

Cycloclypeus carpenteri Brady	common
Sporadotrema cylindricum (Carter)	rare
Miniacina miniacea (Pallas)	rare
Carpenteria sp.	rare
Amphistegina radiata (Fichtel and Moll)	rare

4) Lat. 24°27'26"N; Long. 123°05'15"E; depth 71 m. East of Yonaguni-jima. CALCAREOUS SAND: Features same as the preceding; contains the following species of Foraminifera listed below, Bryozoa, and abundant Halimeda; however no Cycloclypeus is found.

Sorites marginalis Lamarck	rare
Amphistegina radiata (Fichtel and Moll)	rare
Calcarina spengleri Linnaeus	rare
Calcarina hispida Brady	not rare
Heterostegina depressa d'Orbigny	common
Miniacina miniacea (Pallas)	rare

5) Lat. 24°27'29"N; Long. 123°04'44"E; depth 127 m. Southeast of Yonaguni-jima. BRYOZOAN SAND: Light brown, incoherent, apparently washed, consists mainly of Bryozoa, besides sponge spicules, alcyonarian spicules and the following Foraminifera:

Cyclocypeus carpenteri Brady	rare
Operculina ammonoides (Gronovius)	rare
Amphistegina radiata (Fichtel and Moll)	common

and other smaller benthonic and pelagic forms

6) Lat. 24°28'54"N; Long. 124°50'26"E; depth 103 m. South of Tarama-jima. CALCAREOUS SAND: White, granular, quite incoherent, appearing as if washed; contains the following species of Foraminifera:

Cycloclypeus carpenteri Brady	abundant
Operculina ammonoides (Gronovius)	common
Miniacina miniacea (Pallas)	common

7) Lat. 24°29'24"N; Long. 124°53'44"E; depth 81 m. South of Tarama-jima. CALCAREOUS SAND: has the same appearance as the preceding, containing the following species of Foraminifera:

Cycloclypeus carpenteri Brady	very common
Baculogypsinoides spinosus Yabe and Hanzawa ?	rare
Calcarina hispida Brady	rare
Heterostegina depressa d'Orbigny	rare
Operculina ammonoides (Gronovius)	rare
Amphistegina radiata (Fichtel and Moll)	very common
Miniacina miniacea (Pallas)	rare

8) Lat. 24°30'46"N; Long. 124°52'30"E; depth 87 m. South of Tarama-jima. CALCAREOUS SAND: Of the same character as the preceding; contains the following species of Foraminifera:

Cycloclypeus carpenteri Brady	very common
Operculinella cumingii (Carpenter)	rare
Amphistegina radiata (Fichtel and Moll)	rare
Miniacina miniacea (Pallas)	rare

Remarks: The occurrence of Operculinella cumingii (Carpenter) is here first recorded from the seas north of the Philippines.

9) Lat. 24°36'57"N; Long. 122°18'25"E; depth 132 m. Off Karenko, east coast of Formosa. CALCAREOUS SAND: Dirty light brown, incoherent, apparently washed; contains coral fragments encrusted with calcareous algae, Pteropoda, Bryozoa, an ahermatypic coral, Cryptohelia cf. japonica Yabe and Eguchi, and the following species of Foraminifera:

Cycloclypeus carpenteri Brady	common
Amphistegina radiata (Fichtel and Moll)	common

10) Lat. 24°37'07"N; Long. 124°48'0 "E; depth 82 m. South of Tarama-jima. CAICAREOUS SAND: White, granular, incoherent, contains abundant Bryozoa, Mollusca, and the following species of Foraminifera:

Cycloclypeus carpenteri Brady	common
Baculogypsinoides spinosus Yabe and Hanzawa	common
Operculinella cumingii (Carpenter)	not rare
Operculina ammonoides (Gronovius)	rare
Miniacina miniacea (Pallas)	common
Homotrema rubrum (Lamarck)	rare
Sorites marginalis (Lamarck)	rare
Amphistegina radiata (Fichtel and Moll)	common
Cibicides refulgens (Montfort)	rare
Hauerina fragilissima (Brady)	rare
Massilina secans d'Orbigny	rare
Elphidium craticulatus (Fichtel and Moll)	rare
Pseudogaudryina sp.	rare
Borelis pygmaeus schlumbergeri Reichel	very rare

Remarks: Borelis pygmaeus schlumbergeri Reichel (1936, pp. 110-112, pl. 10, fig. 1-3; pl. 11) cited above is also the first record of the occurrence from the Pacific, since it was described from the Western Indian Ocean.

11) Lat. 24°46'04"N; Long. 124°39'08"E; depth 272 m. East of Minna-jima. CALCAREOUS SAND: Dirty light brown, incoherent, consists of fragmental reef-building corals, Bryozoa, Mollusca and the following Foraminifera:

Homotrema rubrum (Lamarck)	rare

12) Lat. 24°49'26"N; Long. 124°37'56"E; depth 235 m. South of Tarama-jima. PTEROPOD OOZE: White, incoherent, apparently washed, contains abundant Pteropoda and the following species of Foraminifera:

Miniacina miniacea (Pallas)	common
Amphistegina radiata (Fichtel and Moll)	common
Ammobaculites reophaciformis Cushman	common
Calcarina spengleri Linnaeus	common
Operculina philippinensis Cushman	rare
Textularia haureii d'Orbigny	rare
T. stricta Cushman	rare
Cycloclypeus carpenteri Brady	present

Eponides praecinctus (Karrer)	common
Orbulina universa d'Orbigny	abundant
Globigerina bulloides d'Orbigny	common
G. triloba Reuss	common
G. inflata d'Orbigny	common
Globigerinoides conglobatus (Brady)	common
Glandulina sp.	rare
Pyrogo sp.	rare

13) Lat. 24°49'46"N; Long. 124°38'58"E; depth 120 m. North of Tarama-jima. CALCAREOUS SAND: White, granular, quite incoherent, consists of coral fragments encrusted with calcareous algae and the following species of Foraminifera:

Cycloclypeus carpenteri Brady	rare
Baculogypsinoides spinosus Yabe and Hanzawa ?	not rare
Heterostegina depressa d'Orbigny	rare
Amphistegina radiata (Fichtel and Moll)	rare

14) Lat. 24°51'24"N; Long. 124°36'04"E; depth 340 m. North of Minna-jima. PTEROPOD OOZE: White, granular, incoherent, apparently washed; contains abundant Pteropoda, Pelecypoda, fish otoliths, Alcyonarian spicules Ahermatypic corals and Foraminifera:

Ahermatypic corals:

Bathyactis symmetrica (Pourtaleo)
Caryophyllia cf. scobinosa decapali Yabe and Eguchi

Foraminifera are:

A few Amphistegina radiata (Fichtel and Moll) and abundant smaller forms including the Globigerinidae.

15) Lat. 24°54'19"N; Long. 124°44'24"E; depth 321 m. Northeast of Tarama-jima. PTEROPOD OOZE: Having the same character as the preceding; contains abundant fragmental Pteropoda and Pelecypoda, and small Foraminifera as follows:

Orbulina universa d'Orbigny	very common
Globigerina bulloides d'Orbigny	common
G. triloba Reuss	common
G. conglomerata Schwager	common
Globigerinoides sacculinferus (Brady)	common
G. conglobatus (Brady)	common
Globigerinella subcretacea (Lomnicki)	common
Globorotalia truncatulinoides (d'Orbigny)	common
G. menardii (d'Orbigny)	common
Sphaeroidina bulloides d'Orbigny	common
Cymbalopora squamosa (d'Orbigny)	common
C. bradyi (Cushman)	common

Discorbis procera (Brady)	common
D. orbicularis (Terquem)	common
D. subbertheloti Cushman	common
Siphogenerina raphana (Parker and Jones)	not common
Cassidulina orientale (Cushman)	not common
C. subglobosa Brady	not common
Spiroloculina canaliculata d'Orbigny	not rare
Triloculina circularis Bornemann	not rare
T. oblonga (Montagu)	not rare
Cibicides labatulus (Walker and Jacob)	not rare
Dyocubicides sp.	rare
Spirillina sp.	not rare
Patellina corrugata Williamson	not rare
Bifarina fimbriata (Millett)	very rare
Bifarinella ryukyuensis Cushman and Hanzawa	rare
Bolivina robusta Brady	not rare
B. subreticulata Parr	rare
Chrysalininella dimorpha (Brady)	not rare
Eponides Karsteni (Reuss)	

Remarks: Bifarinella ryukyuensis was first described by Cushman and me as a new species and new genus from the Ryukyu limestone of Kamikatetsu, Kikai-jima (1936).

16) Lat. 25°15'53"N; Long. 125°47'28"E; depth 45 m. Between Miyako-jima and Okinawa-jima. CALCAREOUS SAND: White, granular, quite incoherent, has the appearance of having been washed; contains Bryozoa, calcareous algae, Mollusca, Alcyonarian spicules, and the following species of Foraminifera.

Sorites marginalis Lamarck	not rare
Amphistegina radiata (Fichtel and Moll)	common
Baculogypsinoides spinosus Yabe and Hanzawa	common
Heterostegina depressa d'Orbigny	common
Miniacina miniacea (Pallas)	rare
Homotrema rubrum (Lamarck)	rare
Planorbulinella larvata (Parker and Jones)	rare

Besides, numerous smaller forms including the Globigerinidae were found, but no Cycloclypeus is present.

17) Lat. 25°17'30"N; Long. 125°49'50"E; depth 91 m. Between Miyako-jima and Okinawa-jima. CALCAREOUS SAND: White, granular, quite incoherent, apparently washed, contains the following Foraminifera:

Cycloclypeus carpenteri Brady	common
Baculogypsinoides spinosus Yabe and Hanzawa ?	very rare
Heterostegina depressa d'Orbigny	very rare

18) Lat. 25°18'03"N; Long. 125°47'47"E; depth 55 m. Between Miyako-jima and Okinawa-jima. CALCAREOUS SAND: White mottled with light brown coarsely granular, incoherent, consists of coral fragments, Lithothamnion, and the

following Foraminifera:

Acervulina inhaerens Schultze	not rare
Cycloclypeus carpenteri Brady	rare
Amphisorus hemprichi Ehrenberg	rare
Homotrema rubrum (Lamarck)	rare
Amphistegina radiata (Fichtel and Moll)	not rare

Besides other smaller forms including Globigerinidae

19) Lat. 25°19'04"N; Long. 125°50'33"E; depth 106 m. Between Miyako-jima and Okinawa-jima. CALCAREOUS SAND: White, granular, incoherent, apparently washed; contains Bryozoa and the following Foraminifera:

Acervulina inhaerens Schultze	not rare
Cycloclypeus carpenteri Brady	common
Operculina bartschi Cushman	not common
Calcarina hispida Brady	common
Amphistegina radiata (Fichtel and Moll)	rare
Homotrema rubrum (Lamarck)	rare

Besides abundant smaller forms including Globigerinidae

20) Lat. 25°20'33"N; Long. 125°50'07"E; depth 62 m. Between Miyako-jima and Okinawa-jima. CALCAREOUS SAND: Varicoloured, granular, incoherent, apparently washed, contains Bryozoa and the following Foraminifera:

Cycloclypeus carpenteri Brady	common
Baculogypsinoides spinosus Yabe and Hanzawa	common
Heterostegina depressa d'Orbigny	rare
Amphistegina radiata (Fichtel and Moll)	not rare

21) Lat. 25°24'13"N; Long. 125°46'01"E; depth 120 m. Between Miyako-jima and Okinawa-jima. CALCAREOUS SAND: White, granular, incoherent, apparently washed; contains the following Foraminifera:

Cycloclypeus carpenteri Brady	abundant
Operculina bartschi Cushman	rare
O. ammonoides (Gronovius)	common
Calcarina hispida Brady	common
Gypsina globulus Reuss	rare
Amphistegina radiata (Fichtel and Moll)	common

22) Lat. 25°55'00"N; Long. 124°35'00"E; depth 297 m. Near Sekibisho, north of Minna-jima. BRYOZOAN SAND: Dirty light brown, incoherent, apparently washed; contains abundant Bryozoa, and the following Foraminifera:

Calcarina spengleri Linneus	common
C. defrancii d'Orbigny	common
Textularia sagittula Defrance	common
T. gramen d'Orbigny	not common
Operculina ammonoides (Gronovius)	rare
Heterostegina depressa d'Orbigny	not common

Sorites marginalis Lamarck	not common
Praesorites orbitolitoides Hofker	not common
Spiroloculina canaliculata d'Orbigny	not common
Schlumbergerina alveoliniformis (Brady)	rare
Cornuspira involvens Reuss	not rare
Quinqueloculina tropicalis Cushman	rare
Q. lamarckina d'Orbigny	not rare
Pyrgo bradyi (Schlumberger)	rare
P. lucernula (Schwager)	rare
Dentalina soluta Reuss	rare
Eponides repandus (Fichtel and Moll)	common
Discorbis opercularis (d'Orbigny)	not rare
Planorbulinella larvata (Parker and Jones)	rare
Globigerina bulloides d'Orbigny	very common
G. inflata d'Orbigny	common
G. triloba Reuss	common
G. conglomerata Schwager	common
G. digitata Brady	common
Globigerinoides sacculiferus (Brady)	common
Pulleniatina obliquiloculata (Parker and Jones)	common
Orbulina universa d'Orbigny	very common
Globorotalia truncatulinoides (d'Orbigny)	common
G. menardii (d'Orbigny)	common

The marine deposits now dealt with were collected by the S.S. MATSUYE from the sea bottom neighboring the Sakishima subgroup of the Ryukyu Islands in the area between Latitudes 24°11'N. and 25°55'N; and Longitudes 122°18'E. and 125°55'E. Their bathymetrical range is from 45 to 340 m. All the specimens of the marine sediments are scanty in amount, and each weighs only a few tens of grams. Although the quantity of each sample is probably insufficient for a thorough study of the Recent fauna found in the sublittoral and shelf sediments in this district, a general picture of the faunal character can be gained.

3. Ecology of Some Important Foraminifera

Cycloclypeus carpenteri Brady

As far as the present material is concerned, Cycloclypeus carpenteri Brady ranges in depth from 55 to 133 m. and has never been found at depths less than 50 m. or more than 200 m. It grows luxuriantly on the bottom at about 100 m. in depth. This species, as well as Baculogypsinoides spinosus Yabe and Hanzawa, is not found in the littoral deposits of the Ryukyu Islands, nor in any part of the Indopacific region. But Calcarina spengleri Linnaeus and Baculogypsina sphaerulata (Parker and Jones) are very common in the beach sands of this region.

F. Chapman (1899, pp. 21-26, pl. 2, figs. 1, 2, 6, 7, etc.) recorded the occurrence of this species from the Funafuti Atoll, Ellice Islands. According to him, this species has never occurred in lagoon dredgings, but it is found on the outside of the atoll in depths from 50 to 360 m. and occurs in the greatest profusion at a depth of 90 to 100 m.

According to J. Hofker (1927, pp. 71-74, pl. 24, fig. 1; pl. 37; pl. 38, figs. 1-9, 12, 13) who studied the Foraminifera in the marine deposits collected by the Siboga Expedition, Cycloclypeus carpenteri is recorded from 32 to 1419 m. and it is common in the sediments at a depth of 32 to 67 m. This species is recorded by H. B. Brady (1884, p. 751, pl. 111, figs. 8a, b) in the Challenger samples from Fiji at a depth 38 m. J. A. Cushman also described this species from the neighboring sea of the Philippines. According to him, this species is common in this region from 43 to 1,000 m.

Remarks: J. Hofker described bivalent and trivalent individuals of Cycloclypeus carpenteri (1927, pl. 12, figs. 1-3), as well as its normal megalospheric form. It seems to me to be worthy of note that I found many, not only bivalent and trivalent individuals of Cycloclypeus carpenteri, but also quinquevalent individuals in the present Recent material. These abnormal forms are quite similar to the normal individuals in external appearance. They are smooth or sometimes papillated on the surface of the test, and are provided with a thick lenticular central boss surrounded by a thin wafer-like peripheral flange. They are usually larger than the normal form and provided with a thicker umbo. The embryonic apparati of the abnormal forms are disposed on the equatorial plane of the test, although some deviate very slightly from this plane.

A foraminifer described by Mobius from the Maritius as Heterostegina tubercalata Mobius (1880, p. 107, pl. 12, figs. 3-7) is a Cycloclypeus. In the material at my disposal, the embryonic chambers of the normal megalospheric individuals show the characteristic features of C. carpenteri, but the dimensions of the chambers vary widely. The Mauritius form mentioned above seems to me to have a very small proloculus. I am now inclined to refer to Cycloclypeus carpenteri a similar form of Cycloclypeus found in the present material from the Ryukyu Islands.

Alveolinella quoyi (d'Orbigny)

According to Brady's information in the Challenger reports (1884, p. 222, pl. 17, figs. 7-12), Alveolinella quoyi (d'Orbigny), "It most affects the shallow water of the coral reefs, and becomes rare at greater depth than 54 fathoms." But it is not found in the littoral zone of the coral reef regions in Formosa, the Ryukyu or Bonin islands or in Micronesia.

Cushman recorded this species from the seas neighboring the Philippines at depths from 18 to 68 m. According to him, it is most abundant at depths of 18 to 58 m. and becomes rare at a depth of 68 m. At Funafuti, according to Chapman, (1899, p. 414), it occurred from 90 to 109 m.

In the East Indies, according to J. Hofker's study on the Siboga material, (1930, p. 167) this species ranges from 9 to 45 m. and is abundant at 22 m. at Tual-anchorage, Kei Islands.

Alveolinella quoyi is common in the Ryukyu limestone, but I have not found it in the Recent material. I have found a single specimen of alveolinid in the samples from Lat. 24°37'07"N; Long. 124°48'00"E; depth 82 m. south of

Tarama-jima. I assigned it to a Recent species Borelis pygmaeus schlumbergeri Reichel from Mayotte I., northwest of Madagascar (1936, pp. 110-112, pl. 10, figs. 1-3; pl. 11). According to M. Reichel, the conditions under which the material was discovered are not known. As already stated by M. Reichel, Alveolina longa (Cziczek) described by C. E. Egger (1893, pp. 57, 58, pl. 3, fig. 32) from the Indian Ocean is identifiable with Reichel's form. The former is found at 137 m. and 411 m. near Mauritius. An alveolinid described by Möbius from Mauruitius as Alveolina boscii Defrance (1880, pp. 79, 80, pl. 3, figs. 13-15, pl. 4, fig. 1) is 1.5-2 mm. long and 0.75 mm. wide and is identifiable with Reichel's form.

Baculogypsinoides spinosus Yabe and Hanzawa

A foraminifer identical with the present Recent form of Baculogypsinoides was described by Cushman (1921, p. 358, pl. 75, fig. 5, pl. 76, figs. 1-5) from the seas bordering the Philippines and by Hofker from the sea bottom near the East Indies (1927, p. 48, pl. 23, pl. 24, figs. 1-7, 9). It is common from 18 to 620 m. in the Philippines and abundant in the East Indies up to 32 m.

The ecological conditions of Cyclolypeus carpenteri, Alveolinella quoyi, and Baculogypsinoides spinosus described above indicate that the Ryukyu Limestone containing these three species, was deposited as a neritic sediment, not as a littoral one, under climatic conditions similar to or possibly warmer than those prevailing in the Ryukyu Islands today.

Literature Cited

Brady, H. B. — Report on the Foraminifera, dredged by H.M.S. CHALLENGER during the years 1873-1876: Rep. Voy. Challenger, Zool. vol. 9, pp. 1-814, pls. 1-115, 1884.

Chapman, F. — On some new and interesting Foraminifera from the Funafuti Atoll, Ellice Islands: Jour. Linn. Soc., Zool., vol. 28, pp. 1-32, pls. 1-5, 1899.

——— — A summary of the Foraminifera found at depths from 16 to 200 Fathoms around Funafuti in dredgings made by Messrs. Halligan and Finckh: Ibid., pp. 397-413, 1899.

——— — On the Foraminifera collected around the Funafuti Atoll from shallow and moderately deep water: Ibid., p. 376, pl. 35, 1902.

Cushman, J. A. — The relationships of the genera Calcarina, Tinoporus, and Baculogypsina as indicated by Recent Philippine material; Contributions to the Biology of the Philippine Archipelago and Adjacent Regions: U. S. Nat. Mus. Bull., vol. 1, pt. 6, pp. 363-368, pls, 44-45, 1919.

Cushman, J. A. — Foraminifera of the Philippine and adjacent seas: Ibid., 100, vol. 4, pp. 1-608, pls. 1-100, text figs. 1-52, 1921.

——— — The Foraminifera of the tropical Pacific collections of the ALBATROSS, 1899-1900: Ibid., 161, pt. 2. Lagenidae to Alveolinellidae, pp. i-vi, 1-79, pls. 1-19, 1933.

Cushman, J. A. and Hanzawa, S. — New genera and species of Foraminifera of the Late Tertiary of the Pacific: Contr. Cushman Lab. Foram. Res. vol. 19, pt. 2, pp. 45-48, pl. 8, 1936.

Egger, C. E. — Foraminiferen aus Meeresgrondproben, gelothet von 1874 bis 1878 von S. M. Sch. Gazelle: Abh. k. bay. Akad. Wiss. 2 Cl. vol. 18, tp. 2, pp. 1(195)-266(458), pls. 1-21, 1 map, 1893.

Gumbel, C. W. — Beiträge zur Foraminiferenfauna der nordalpinen Eocängebilde: Ibid., vol. 10, pt. 2, pp. 1-152, pls. 1-4, 1868.

Hanzawa, S. — Preliminary report on marine deposits from the southwestern North Pacific Ocean: Rec. Ocean. Wks. Japan, vol. 1, No. 2, pp. 59-77, pls. 16, 21, 1928.

——— — Topography and geology of the Riukiu Islands: Sci. Rep. Tohoku Imp. Univ. 2nd ser. (Geol.), vol. 17, pp. 1-61, i-iv, pls. 1-15 text figs. 1-7, 1 chart, 5 geol. maps, 1935.

——— — Revision of "Nummulites" cumingii (Carpenter). Jap. Jour. Geol. Geog. vol. 16, nos. 3-4, pp. 225-232, pls. 15, 16, 1939.

Hofker, J. — Monograph of the Foraminifera; pt. 1: Siboga Expedition, pp. 1-78, pls. 1-38, text figs. 1-11, 1927.

——— — Monograph of the Foraminifera; pt. 2: Ibid., pp. 79-170, pls. 39-64, text figs. 12-31, 1930.

Möbius, K. — Foraminifera von Mauritius: Beiträge zur Meeresfauna der Insel Mauritius und der Seychellen, pp. 63-110, pls. 1-14, 1880.

Nomura, S. and Zinbo, N. — Marine Mollusca from the "Ryukyu Limestone" of Kikai-zima, Ryukyu Group: Sci. Rep. Tohoku Imp. Univ. 2nd ser. (Geol.), vol. 16, no. 2, pp. 109-164, pl. 5, 1934.

Osimo, G. — Di alcuni foraminiferi dell'Eocene superiore di Celebes: Riv. Ital. Pal. vol. 14, pp. 28-54, pls. 1-3, 1908.

Reichel, M. Etude sur les Alveolines: Mem. Soc. Paleont. Suisse, vol. 17, 59, pp. 1-146, pls. 1-11, text figs. 1-29, 1936.

Schlumberger, C. Note sur le genre Tinoporus: Mem. Soc. Zool. France, vol. 9, pp. 87-90, pls. 3, 4, 1896.

Tan Sin Hok On the genus Cycloclypeus Carpenter and Appendix on the Heterostegines of Fjimanggoe, S. Bantam: Java. Wet. Med., no. 19, pp. 3-141, pls. 1-24, tables 1-4, text figs. 1, 2, 1932.

Yabe, H. and Eguchi, M. Deep-water corals from the Riukiu limestone of Kikai-jima, Riukiu Islands: Proc. Imp. Acad. Tokyo, vol. 8, no. 9, pp. 442-445, 1932.

Yabe, H. and Hanzawa, S. A geological problem concerning the raised coral reefs of the Riukiu Islands and Taiwan, etc: Sci. Rep. Tohoku Imp. Univ. 2nd. ser. (Geol.), vol. 7, no. 2, pp. 29-56, pls. 5-10, 1925.

_____ Tertiary foraminiferous rocks of Taiwan (Formosa): Ibid., vol. 14, no. 1, pp. 1-46, pls. 1-16, text fig. 1, tables 1, 2, 1930.

THE ACCUMULATION OF FORAMINIFERAL TESTS IN INLETS OF WAKASA BAY ON THE INLAND SEA OF JAPAN

by

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This study has been made for the purpose of clarifying the environmental factors which affect the accumulation of Recent foraminiferal tests on the sea floor. It may also have an important bearing on the paleoecologic studies of fossil Foraminifera.

The sediments obtained from the bays by the bottom sampler were examined under the microscope and the number of individuals of each species were counted. As a rule, sediments were sampled from the mouth to the head of the bay, in order to cover all of the different environments.

Both Obama and Maizuru Bays are small inlets of Wakasa Bay, which opens on the Japan Sea.

The Form and Conditions of the Small Bays

Obama Bay opens towards the north. The outline resembles a purse with two long pockets and the maximum diameter is about 10 kilometers. The rocky floor is commonly exposed in the surrounding area, especially at the mouth; nearly three quarters of the bottom is covered with soft black mud; only the mouth is floored with gravels and sands. The temperature at the surface in the summer season is 27.5°C. The maximum depth is 26 meters.

Maizuru Bay, which is west of Obama Bay, is a kind of drowned valley, a long narrow inlet branching towards the south and the east with a breadth of about 1,000 meters. The greater part of the bottom is covered with black mud, but gravel and sand are deposited at the mouth. The temperature in May is about 15 to 16°C. at the surface and 14°C. at the bottom. The maximum depth is 30.5 meters.

The Number of Individuals

The total number of individuals obtained from 34 stations in Obama Bay is 48,989; the maximum number from a single station (No. 30), in the middle of the inner part of the mouth, is 13,597; and 34 is the minimum number of individuals from any station (No. 6) in the innermost part of the head. The decrease in the number of individuals may be indicated by concentric circles drawn around Station No. 30 toward the margins of the bay.

In Maizuru Bay, owing to the difference in shape, the distribution pattern of the number of individuals is not in concentric circles, but in regular sequence towards the heads of the inlets. The total population from

26 stations is 8,952, and the maximum number, 3,052, was taken from Station No. 8, at the mouth of the bay; the minimum number, 5, was taken from the station at the innermost head of the inlet.

The Number of Species

The distribution of the number of species in both bays is almost parallel to that of the population.

The total number of species in Obama Bay is 214; the maximum number is 102 from Station No. 30, and the minimum is 10 at the innermost head of the bay.

194 species were taken from stations in Maizuru Bay; Station No. 8 yielded a maximum of 90 and Stations Nos. 39 and 42, at the head of the inlet, a minimum of 3.

Distribution of Some Characteristic Species in Both Bays

There are one or more distribution centers where the number of individuals of each species reaches the maximum. The number of centers may be determined by the shape of bays, the ecologic needs of the species, and the oceanic conditions.

1. Obama Bay.

(a) The mouth of the bay. Tests of Globigerinidae and other planktonic foraminifers are characteristically abundant, and indication of the boundary between the open sea and the bay water. Tests of planktonic Foraminifera are relatively rare inside the bay, but even at the bottom near the mouth, the number of individuals is about 0.5 percent of the whole population of a single station. No other special characters were found.

(b) The central part of the bay. The characteristic and dominant species are Astrononion stelligerum (d'Orbigny), Discorbis patelliformis (Brady), Quinqueloculina seminulum (Linne'), Sigmoilina schlumbergeri Silvestri and Textularia haueri d'Orbigny.

(c) The head of the bay. Trochammina globigeriniforme (Parker and Jones) is the dominant and most characteristic species and the number of individuals exceeds 70 percent of the whole population at a single station. Trochammina nana (Brady) is abundant between the central part of the bay and the head.

2. Maizuru Bay.

In the mouth and innermost heads, the parallels in distribution between Obama and Maizuru Bays are almost perfect. The Globigerinidae at the mouth

and Trochammina globigeriniforme at the head are the characteristic species in both bays under discussion and also in bays on the Pacific side.

In the central part, Textularia haueri d'Orbigny is the dominant species and constitutes 20 to 40 percent of the whole population. Other species characteristic of the central part of Obama Bay are found abundantly near the mouth in Maizuru Bay. The mouth of the Maizuru Bay is very narrow and gives little access to the open sea water. Even at the mouth, the oceanic conditions in Maizuru Bay are nearly similar to those of the central part of Obama Bay. The characteristic bottom species at the mouth are Verneuilina propinqua Brady, Elphidium advenum Cushman, Nonionella pulchella (Hada), and Rotalia beccarii (Linne'), forms common at stations inside the mouth of the Obama Bay.

Relations to Some Environmental Factors

With an area so small as these bays, variations in depth and temperature are not sufficient to affect the distribution of foraminifers. I believe that salinity and bottom characters are the elements which control the distribution of some species.

For example, the fact that Trochammina globigeriniforme is found only at the head of the bay tells us that this species is adapted to a low salinity.

In Obama Bay, species such as Sigmoilina schlumbergeri, Rotalia japonica Hada, Eponides exiguus (Brady), etc., like to gather on the muddy bottoms; Spiroloculina depressa d'Orbigny, Cibicides lobatulus (Walker and Jacob), Cibicides refulgens Montfort, etc., on the other hand, are most common on the sandy floor.

Selected Bibliography

Habe, T. and others. On Thanatocoenoses of the Obama Bay: Jour. Physiology and Ecology, Kyoto Imp. Univ., no. 32, 1945.

Miyadi, D. and Habe, T. Biocoenoses and Thanatocoenoses of the Nakanoumi: Ibid., no. 31, 1945.

_____ On Thanatocoenoses of Bays: Physiology and Ecology, Kyoto, vol. 1, no. 2, 1947.

Wasmund, E. Biccoenose und Thanatocoenose, Biosoziologische Studie über Lebens gemeinschaften und Totengesellschaften: Arch. f. Hydrobiol., no. 17, 1926.

STUDIES OF THE INTERIOR SILURIAN

by
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Bio-stratigraphic studies of the Niagaran deposits in northeastern Illinois begun before the war have been resumed and expanded in the last two years to a survey of the Silurian outcrops of the interior province west of the Cincinnati geanticline (Michigan, Wisconsin, Iowa, Oklahoma, Arkansas, Missouri, Tennessee, Kentucky, and Indiana). The aim of this survey has been to establish a regional facies frame for a more detailed study of the Silurian facies relations below the surface in Illinois, with particular reference to the occurrence and distribution of subsurface reefs. This study has been prompted by the discovery of a subsurface reef covering six square miles, which forms the reservoir rock of the Marine Pool in Madison County, Illinois. The occurrence suggests that this large reef may possibly be linked by others to the reef archipeligo that skirts the Michigan basin.

The most important result of these studies to date has been the realization that the differences that had long been noted between the faunas of the Niagaran belt along the southern rim of the Michigan basin as compared with those of the southern Indiana-Tennessee areas, west of the Cincinnati geanticline are not provincial differences as had been assumed by Schuchert and independently by Ulrich, but are solely ecologic in nature. To be more specific, it can be demonstrated on the basis of the study of the sponges, crinoids, trilobites and some of the brachiopods and corals in northeastern Illinois, that the typical Racine-Guelphian faunas which were previously interpreted as characteristic faunas of the northern province represent actually the characteristic biocoenoses of the reefs and in part of the reef-bordering, rough-water biotopes. The critical elements previously thought to characterize the southern province, and restricted to it, occur in the still-water biotopes adjacent to the reefs where they form not only endemic but at the same time the characteristic assemblages. A typical example of the occurrence of so-called southern and northern faunas side by side can be seen in the Thornton quarry south of Chicago. Here, the Astylospongidae, Pisocrinidae and Gissocrinidae, a typical "southern" assemblage, form the common elements of the muddy inter-reef bottoms, and at times during quiet water intervals occupied the lower reaches of the flanks of the Thornton reef which contains the characteristic "northern" Racine-Guelphian faunas.

The faunal succession of the open epi-continental shelf deposits of early Niagaran times and of the still-water to semi-rough-water, inter-reef deposits of the higher reef bearing strata of the Niagaran in northeastern Illinois and northern Indiana, parallels essentially that of the normal Niagaran deposits of the southern outcropping belt (where reefs are absent) demonstrating, contemporaniety (contrary to Ulrich's concept) and at the same time non-existence of a separating barrier (contrary to Schuchert) between the northern and southern

portions of the epi-continental shelf sea west of the Cincinnati swell. The regional distribution and succession of the diagnostic sponges, crinoids, and trilobites, as far as they have been studied to date link the Niagaran faunas along the Ozark border that is, Oklahoma, Arkansas, Tennessee, Kentucky, and Missouri to those of northeastern Illinois—northern Indiana, pointing toward a single faunal province north of the southwestern portion of the Appalachian geosyncline and west of the Cincinnati geanticline, in which faunal differences can be related to biotope differentiations. The northern border of this faunal province is at present not clearly defined. It is still uncertain whether the radical faunal differences of the pre-Guelphian faunas on either side of a line running roughly NE-SW (south of the outcropping Silurian of Iowa, northwestern Illinois, northern Wisconsin, across the Michigan basin) are ecological or of a provincial nature. In Guelph time, this regional differentiation breaks down, as the Guelphian faunas extend southward across the line, in the reef biotopes as far south as reefs have been observed.

A series of maps, showing the major features of facies relations within this province are in preparation. They will form the basis for animal geographic studies, which have been started for a number of crinoid and sponge genera and will show facies tolerance, geographic distribution and specific variation within their distribution areas.

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